FLUCTUATIONS OF THE NISQUALLY GLACIER, MT. RAINIER, WASHINGTON, SINCE 1750

By A. E. HARRISON

ABSTRACT. A history of the fluctuations of the Nisqually Glacier on the southern slope of Mt. Rainier, Washington, including the period of increased glacial activity during the last ten years, indicates that a number of minor advances have occurred since the maximum extension of the ice about 1750. These new data on glacial activity in the United States of America should be useful in examining the idea of synchronism in glacial behavior in different regions of the world. In addition, photographs of the changes in the Nisqually Glacier during the last four years indicate the magnitude of the recent increase in glacial activity in this country.

ZUSAMMENFASSUNG. Die Geschichte der Schwankungen des Nisqually Glacier auf dem südlichen Hang des Mt. Rainier, Washington, einschliesslich der Periode der verstärkten Gletschertätigkeit während der letzten zehn Jahre, zeigt dass eine Anzahl geringerer Vorstösse seit der maximalen Ausbreitung des Eises um 1750 erfolgt sind. Diese neuen Angaben über Gletschertätigkeit in den Vereinigten Staaten von Amerika sollten beim Studium des Gedankens der Synchronisierung im Verhalten der Gletscher in verschiedenen Regionen der Welt nützlich sein. Noch dazu zeigen Photographien der Veränderungen im Nisqually Glacier während der letzten vier Jahre die Grösse des jüngst statthabenden Anwachsens der Gletschertätigkeit in diesem Lande an.

INCREASED glacial activity in the western United States during the last ten or fifteen years has emphasized the inadequacy of an over-simplified theory of synchronism in glacial behavior in different parts of the world, because this increased activity has been absent in many regions and either absent or unnoticed in most parts of the world. It is evident that additional data on past glacial fluctuations in the United States, as well as a history of the recent growth of glaciers in this country, would be important in evaluating the usefulness and limitations of the idea of synchronism. The Nisqually Glacier on Mt. Rainier in the State of Washington has been chosen for study because it has been observed more frequently than other glaciers in the United States. There is evidence that other glaciers in this region have behaved in a similar manner, therefore it is logical to continue studies on the best-known glacier if this glacier is a typical example of glaciation in the region.

Although it has been generally believed that glaciers in the United States have receded continuously since the time of the discovery of the Nisqually Glacier by Lieutenant A. V. Kautz in 1857, two minor advances at the terminus have actually occurred during this time. More advances might have occurred if the conditions at the terminus had remained indicative of the health of the glacier. The ice near the terminus has been too thin to have glacial movement for several decades and retreat of the terminus is inevitable under these conditions. Recession would be much more rapid, even during this period of glacial growth, if this stagnant ice were not protected from melting by a thick cover of debris.

The area included in these studies is shown in Fig. 1 (p. 676), a map prepared from aerial photographs made for the United States Geological Survey in 1951. The positions of moraines and trimlines have been indicated in relation to the present area of the ice. The active ice is now a short distance below a constriction in the glacier less than a mile above the terminus, and is indicated by a change in the cross hatching.

A better idea of the conditions existing at the Nisqually Glacier at present can be gained from the photograph in Fig. 2 (p. 680). The sloping ice face at the bottom left of the picture where the river emerges is considered the terminus of the glacier, although ice extends a short distance below this point on both sides of the river. The stagnant portion of the ice is deeply gullied and covered with debris. The active portion of the glacier has pushed past the rock shoulder in the center of the picture and forms a convex bulge with a rather sharp boundary, suggesting that the active ice may be over-riding the thin, stagnant ice without becoming fused with it.

An increase in the thickness of ice in the higher portion of the Nisqually Glacier was first observed by Arthur Johnson [1] about ten years ago, and the progress of this "wave" of increased ice thickness has been measured by Johnson each year since that time. The position of the front of the wave will be defined as the transverse line across the glacier where the flow of ice from above just equalizes the melting and the surface height neither increases nor decreases. The

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velocity of the wave "front" in the higher, active portion of the glacier was about 700 ft. (213 m.) per annum, more than twice the velocity of the ice itself at the surface of the glacier. This rapid advance was halted in 1951, when the wave reached the rock barrier in the center of Fig. 2, probably because the barrier extends across the canyon under the ice, and partly as a result of two seasons of an excess of ablation over accumulation in 1951 and 1952.

Conditions have been favorable for glacial growth again since 1953, and the wave is pushing past the rock shoulder. Its progress in the past four years has not been measured quantitatively, but can be recognized easily in the three telephoto pictures made in 1951, 1953 and 1955 and shown in Fig. 3 (p. 680). Another observation of some interest is that the crevasse patterns suggest that the ice is being forced by an underlying rock ridge to follow a devious path around the rock shoulder.

Photographs of this same area made by the National Park Service in 1932, plus the existence of a new moraine on the side of the rock shoulder below the 1932 position of the ice, indicate that

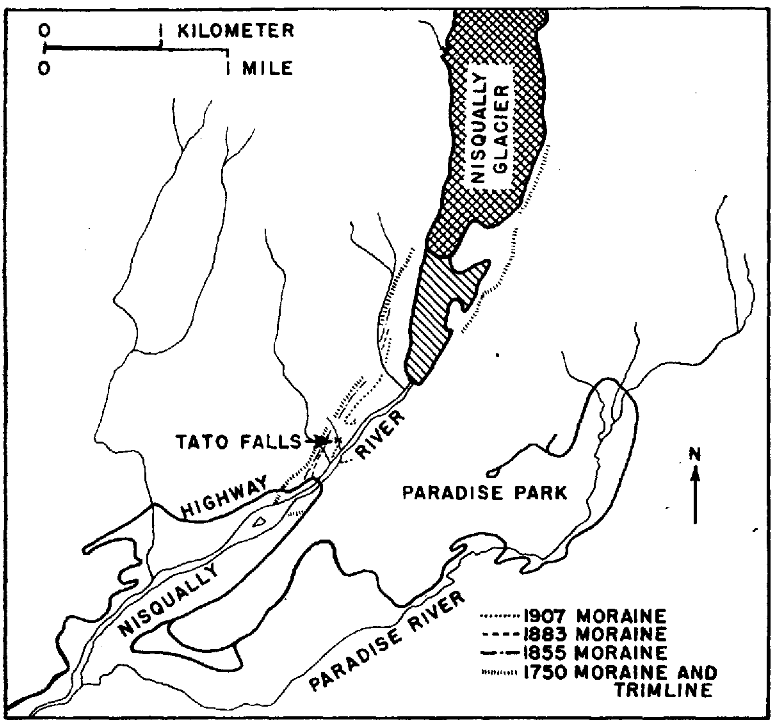

Fig. 1. Map of the Nisqually Glacier, Mt. Rainier, Washington, showing location of recent moraines with respect to the area of ice at present. The areas of active ice and the stagnant ice above the terminus are indicated by the change in cross hatching

a similar wave of ice reached this point between 1932 and 1936. This earlier increase in glacial activity was not as pronounced as the present one, and apparently died out before reaching the terminus of the glacier.

Other periods of minor growth may have occurred, but evidence of these periods has not been preserved. It has been possible to reconstruct a partial history of the larger fluctuations of the Nisqually Glacier during the last 200 years from reports of old surveys, old photographs and the dating of moraines and trimlines from tree-ring counts. A summary of these data on the position of the terminus of the Nisqually Glacier, including the sources of information, has been tabulated below and the data have been plotted in Fig. 4, p. 683. All distances are in meters and

(*continued on page* 681)

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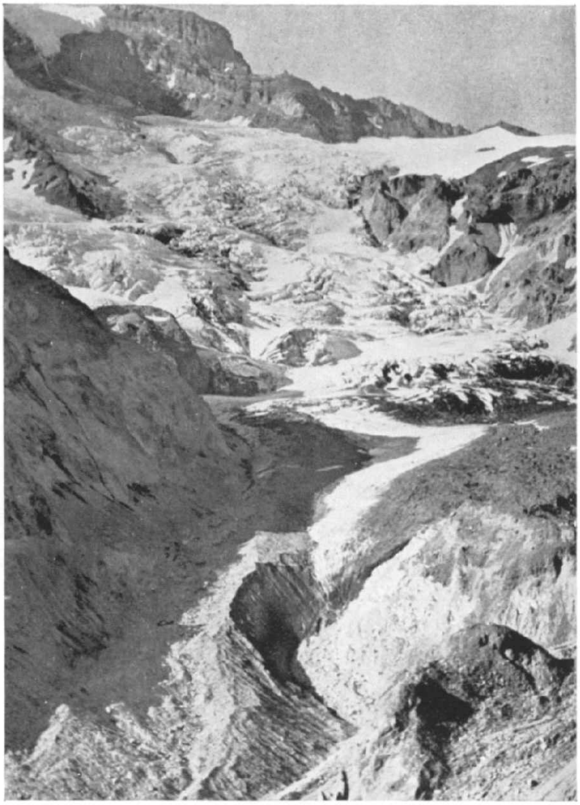
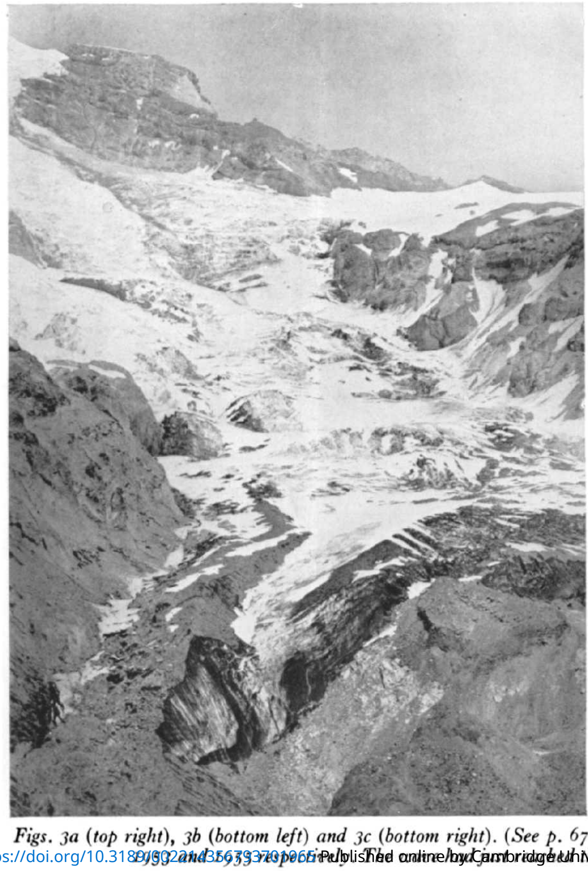
Fig. 2. (See p. 675.) View of Mt. Rainier and the Nisqually Glacier from Nisqually Vista, a point on the rim of the canyon just above the terminus of the glacier





Figs. 3a (top right), 3b (bottom left) and 3c (bottom right). (See p. 676.) Telephoto views of the ice wave on the Nisqually Glacier in 1951, 1952 and 1953 respectively. [illegible] rock in the lower right corner in Fig. 3a are measured horizontally from the north side of the highway bridge across the Nisqually River. Positions indicated by negative distances are downstream from the bridge. Some earlier, tentative data [2, 3] have been modified slightly, but earlier conclusions are essentially correct.

LOCATION OF THE NISQUALLY GLACIER FRONT IN RELATION TO THE PRESENT NISQUALLY BRIDGE

Year	*Distance from Bridge in meters*	*Source of data*
1750	−500	Estimated age of trees from incomplete ring count
1825	−107	Ring count of trees in area not covered by 1855 ice
1855	−107	Ring count inside trimline; A. V. Kautz description [4]
1870	−46	Descriptive report by S. F. Emmons [5]
1883	−46	Moraine 3 meters high with three closely spaced loops
1884	−30	A. C. Mason photograph (Tacoma City Light No. 2678)
1885	0	James Longmire report [6]
1893	+350	E. T. Allen photograph (Park Museum, Longmire)
1903	335	O. A. Piper photograph (Park Museum, Longmire)
1905	290	Joseph N. LeConte measurement [7]
1907	259	Single moraine 1 meter high
1908	267	Single moraine less than 1 meter high, Ray Kautz measurement [8]
1910	317	F. E. Matthes measurement [9]
1915	380	Asahel Curtis photograph No. 33159 [10]

MEASUREMENTS BY NATIONAL PARK SERVICE [11]

1918	442	1928	654	1938	877	1948	1123
1919	460	1929	670	1939	904	1949	1161
1920	474	1930	705	1940	925	1950	1181
1921	506	1931	721	1941	961	1951	1203
1922	526	1932	736	1942	979	1952	1226
1923	540	1933	749	1943	1003	1953	1241
1924	565	1934	796	1944	1029	1954	1255
1925	587	1935	813	1945	1049	1955	1279
1926	614	1936	845	1946	1062		
1927	626	1937	850	1947	1096		

A minor change has been made in the tabulated data since these data were first published[3]. The date of the maximum extent of the ice after 1900 was first estimated as 1906, and the two moraines were tentatively dated 1906 and 1907, based on the fact that a 1908 photograph showed the ice definitely behind its recent maximum extent. However, Ray Kautz, the engineer who built the original bridge across the river in 1908, measured the distance from the bridge to the ice and this distance checks with the estimated position where the second, smaller moraine would intersect the river channel. For this reason it seems logical to assume that the two moraines correspond to 1907 and 1908 instead of 1906 and 1907.

Several questions regarding the interpretation of the gaps in the record naturally arise when the graph in Fig. 4 (p. 683) is examined. The rapid rate of recession between 1884 and 1893, apparently much greater than in recent times, was surprising. It was natural to suspect an error in the date of one or both of the pictures used to establish the position of the front in those years. The validity of the date of the 1884 photograph is substantiated by Willis' report [12] of an active, advancing front at the North Mowich Glacier (Willis Glacier) on the north-west side of Mt. Rainier in 1881 and 1885. The E. T. Allen photograph was obviously taken several years before 1903, since there is no sign in this picture of the increased ice thickness needed to produce the later advance. In fact, the appearance of the front in 1893 and the gullied surface of the glacier gives testimony that excessive ablation had taken place in previous years.

The 1855 advance has been dated by tree-ring counts and an estimated lag of 50 years in the germination of coniferous trees at a definite trimline at the position of a very poorly defined moraine. This date is decidedly uncertain, but the nature of the 1855 and 1907 moraines is similar, and suggests that the 50 year lag at the 1907 moraine might also be reasonable for the 1855 advance.

This similarity between the moraines of the two advances is also the basis for the conclusion that the 1855 advance represented a rapid forward advance of a relatively clean glacier, followed by an abrupt retreat. If this hypothesis is accepted, then it appears that the 1855 advance was of short duration although the ice moved forward to a position vacated by the glacier thirty years earlier.

This 30 year interval is determined by the difference between the ages of the trees on either side of the trimline. In the event that the lag was less than 50 years, then the interval between deglaciation and re-advance would be less than 30 years, indicating an even shorter duration of the 1855 advance.

The location of the ice at the time of the discovery of the Nisqually Glacier by Lieutenant A. V. Kautz in 1857 has been suggested [6] as 760 ft. (232 m.) below the Nisqually River Bridge. This position was based on an interpretation of A. V. Kautz' description of the glacier [4] but his description could apply equally well to the location of the trimline and faint moraine several hundred feet closer to the bridge. The latter interpretation is probably the correct one, since 80 year old trees grow along the river channel and were used in establishing the position of the proposed 1855 trimline.

The similarity between the structure and size of the 1883 and 1750 moraines suggests that these two advances probably had periods of several years with almost equilibrium conditions. The 1883 moraine may represent a pause in the retreat rather than a re-advance.

A lag of only 35 years in the establishment of an evergreen forest on the 1883 moraine has been established by tree-ring counts. The 1750 date for the maximum extent of the Nisqually Glacier in the last 400 years is based on incomplete ring counts and an assumed lag of 35 years similar to the lag measured at the 1883 moraine. Possible error in the ring counts or a longer lag would make a date of 1740 reasonable, but there is little question that the Nisqually Glacier stood at a maximum extent about 200 years ago. A five foot diameter mature Douglas fir tree 3 ft. from the 1750 moraine was not cored, but indicates that ice had not occupied this part of the canyon for several hundred years prior to 1750.

It seems unlikely that the period between 1750 and 1825 would be free of glacial fluctuations. However, there is no evidence in the young forest of moraines or trimlines to indicate pauses or advances. Ray Kautz reached this same conclusion in 1907 when he chose the site for the road crossing of the Nisqually River. He recalls cutting the roadway through the 1750 and 1883 moraines and remembered no other sign of a moraine or a break in the forest between these two well-defined moraines. (The 1855 trimline is not clearly defined near the roadway, and would have been less apparent 48 years ago.) It is probable that the Nisqually Glacier becomes so greatly extended during times of advance that minor variations of glacial activity never reach the front. This condition occurred in 1936 and may be the fate of the present increase in glacial activity on the Nisqually Glacier.

This history of the fluctuations of the Nisqually Glacier offers the possibility of comparing glacial activity in this region with other regions in the world. Although the advances about 1750 and 1850 correspond to periods of similar activity elsewhere in the world, the later minor advances suggest that the concept of world-wide synchronism should be examined critically. It is unlikely that variations in the time lag between climatic changes and the response of glaciers will account for the discrepancies between periods of minor advances. Certainly the effect of time lag is less important now that we are measuring the immediate response of glaciers to a change in climatic conditions.

Further study is in order before we can determine whether climatic conditions during the earlier advances were greatly different from the conditions which are causing the recent wave of increased ice thickness on the Nisqually Glacier. The margin between glacial growth and shrinkage may be much smaller than generally believed. The opportunity to study the causes of glacial fluctuations while a change is in progress is invaluable and work in this field should be intensified.

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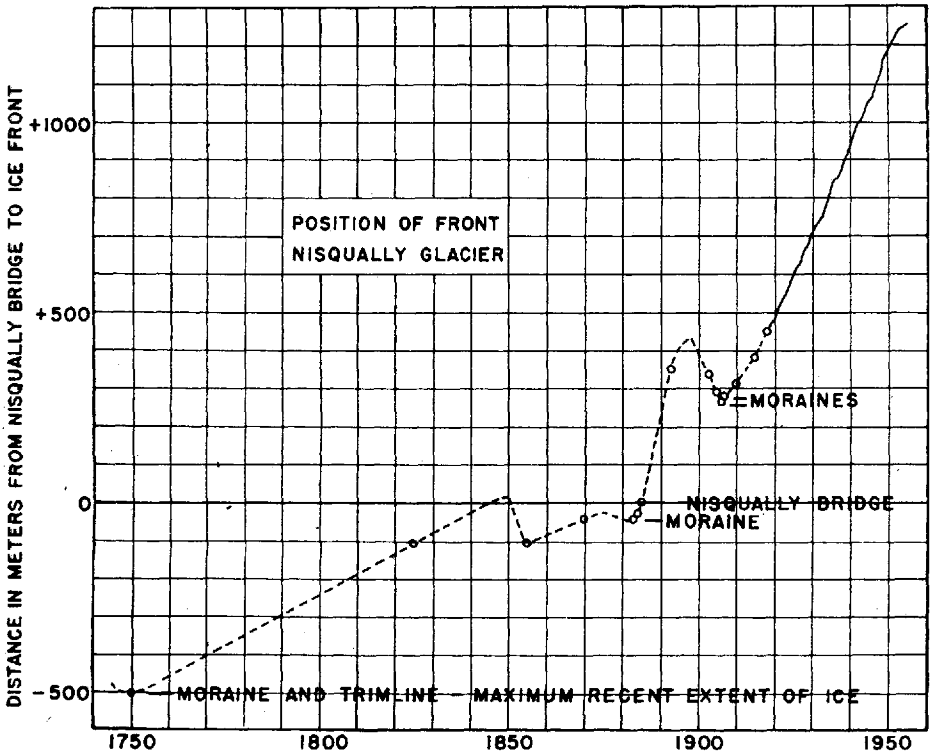

Fig. 4. Plot of the position of the terminus of the Nisqually Glacier since its maximum extent about 1750. The points represent years when the position of the ice has been determined and the dotted lines indicate estimated positions during intervals between measurements. Annual measurements made since 1918 are indicated by a solid line

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