THE RECESSION OF GLACIERS IN MOUNT RAINIER NATIONAL PARK, WASHINGTON

C. FRANK BROCKMAN
Mount Rainier National Park

FOREWORD

One of the most outstanding features of interest in Mount Rainier National Park is the extensive glacier system which lies, almost entirely, upon the broad flanks of Mount Rainier, the summit of which is 14,408 feet above sea-level. This glacier system, numbering 28 glaciers and aggregating approximately 40–45 square miles of ice, is recognized as the most extensive single peak glacier system in continental United States.[1]

Recession data taken annually over a period of years at the termini of six representative glaciers of varying type and size which are located on different sides of Mount Rainier are indicative of the relative rate of retreat of the entire glacier system here. At the present time the glaciers included in this study are retreating at an average rate of from 22.1 to 70.4 feet per year.[2]

HISTORY OF INVESTIGATIONS CONDUCTED ON THE GLACIERS OF MOUNT RAINIER

Previous to 1900 glacial investigation in this area was combined with general geological reconnaissance surveys on the part of the United States Geological Survey. Thus, the activities of S. F. Emmons and A. D. Wilson, of the Fortieth Parallel Corps, under Clarence King, was productive of a brief publication dealing in part with the glaciers of Mount Rainier.[3] Twenty-six years later, in 1896, another United States Geological Survey party, which included Bailey Willis, I. C. Russell, and George Otis Smith, made additional

[1] *Circular of General Information, Mount Rainier National Park* (U.S. National Park Service, 1937), p. 3.

[2] The recession of the Stevens Glacier is excluded, owing to insufficient data.

[3] S. F. Emmons, "On the Discovery of Actual Glaciers on the Mountains of the Pacific Slope," *Amer. Jour. Sci.*, Vol. I (3d ser., 1871), pp. 161–65.

geological investigations. While their work was largely concentrated on the north and northwest slopes of the mountain, they also crossed to the south side, via the summit, being the first party to accomplish this feat. As a result of this survey, I. C. Russell published a detailed account of the major glaciers of Mount Rainier in the *18th Annual Report of the United States Geological Survey*.[4] Russell was the first to call attention to the evidence of glacier recession here, and in his paper he states: "Every glacier about Mount Rainier that was examined by the writer furnished evidence of a recent recession of its terminus and a lowering of its surface. In two instances—the Carbon and the Willis[5] glaciers—rough measurements of the amount of these changes during the past fifteen years were obtained."[6]

The first study of glacier movement in Mount Rainier National Park was made in 1905 by Professor J. N. LeConte, of the University of California. Professor LeConte made a brief investigation of the flow of the Nisqually Glacier during July of that year.[7] Nothing further was undertaken along this line until 1930, when, through the co-operation of the city of Tacoma (Department of Public Utilities), the United States Geological Survey (Water Resources Division), the United States National Park Service, and the United States Bureau of Public Roads, a study of the lower Nisqually Glacier was instituted in an effort to determine the rate of flow in more recent years.[8]

In 1910, 1911, and 1913 the topographic map of Mount Rainier

[4] "The Glaciers of Mount Rainier," *18th Ann. Rept. U.S. Geol. Surv.*, Part II (1897), pp. 350–415.

[5] Now known as the North Mowich Glacier.

[6] No detailed recession data were given, however.

[7] "The Motion of the Nisqually Glacier," *Sierra Club Bull.*, Vol. VI, No. 2 (1907), pp. 108–14. Professor LeConte's observations indicated that an average maximum daily movement of 16.2 inches occurred at a point 558 feet from the east edge of the glacier, and an average minimum daily movement of 6.1 inches occurred 75 feet from the west edge. The glacier was 1,483 feet wide where this study was made, and, while the elevation is not given, it may be assumed from the width of the glacier that it was at about the 5,000-foot level.

[8] Llewellyn Evans, "1931 Progress Report on Nisqually Glacier Study" (1932). (Results of this study were not published, but a typed manuscript is included in the park museum, Mount Rainier National Park, Longmire, Wash.) This report indicates that at an elevation of 5,400 feet the average maximum movement over a period of 246 days (Aug. 31, 1930—June 12, 1931, incl.) was 758.4 inches, or 3.08 inches per day.

National Park was prepared by the United States Geological Survey.[9] The very comprehensive understanding of the glacier system here, which such an undertaking naturally afforded, was productive of the detailed and excellent description of the glaciers of Mount Rainier by F. E. Matthes.[10]

The tabulation of annual recession records on the glaciers of Mount Rainier was first undertaken in 1918, when F. W. Schmoe, the first park naturalist of Mount Rainier National Park, and Professor Henry C. Landes, of the University of Washington, collaborated in the determination of several early locations of the terminus of the Nisqually Glacier by means of old photos and authentic historical records. They also marked the extremity of the ice in that year. Since that date annual data have been taken on the recession of the Nisqually Glacier, first by Schmoe and, since 1928, by the writer, who succeeded Mr. Schmoe in the capacity of park naturalist of this area.

In addition to recession studies made on the Nisqually Glacier, the writer also established markers at the termini of the Emmons Glacier (1930), Carbon Glacier (1930), South Tahoma Glacier (1931), Paradise Glacier (1932), and the Stevens Glacier (1934).[11]

GEOGRAPHIC LOCATION AND CLIMATIC FACTORS

Mount Rainier National Park lies west of the crest line of the Cascade Range, a portion of which forms a part of the eastern park boundary and which is a north-south climatic boundary in the state of Washington. The prevailing winds from the west are heavily laden with moisture from the Pacific Ocean. As these winds rise in passing over the Cascades, rapid condensation of this moisture takes place, which accounts for the heavy precipitation in this area. The existence of the large glacier system on Mount Rainier is, naturally, due to this heavy precipitation. Over 75 per cent of it occurs be-

[9] *Topographic Map of Mount Rainier National Park* (U.S. Geol. Surv., 1934).

[10] *Mount Rainier and Its Glaciers* (U.S. National Park Service, 1922).

[11] "Record of Glacier Recession Measurements Made in Mount Rainier National Park, September, 1937, together with a Summary of Data Previously Taken" (U.S. National Park Service, 1938; typed MS in the library of the park museum, Mount Rainier National Park, Longmire, Washington); C. Frank Brockman, "Glacier Recession in Mount Rainier National Park" (Mount Rainier National Park "Nature Notes," Vol. XV, No. 4 [1937]) (mimeographed bulletin).

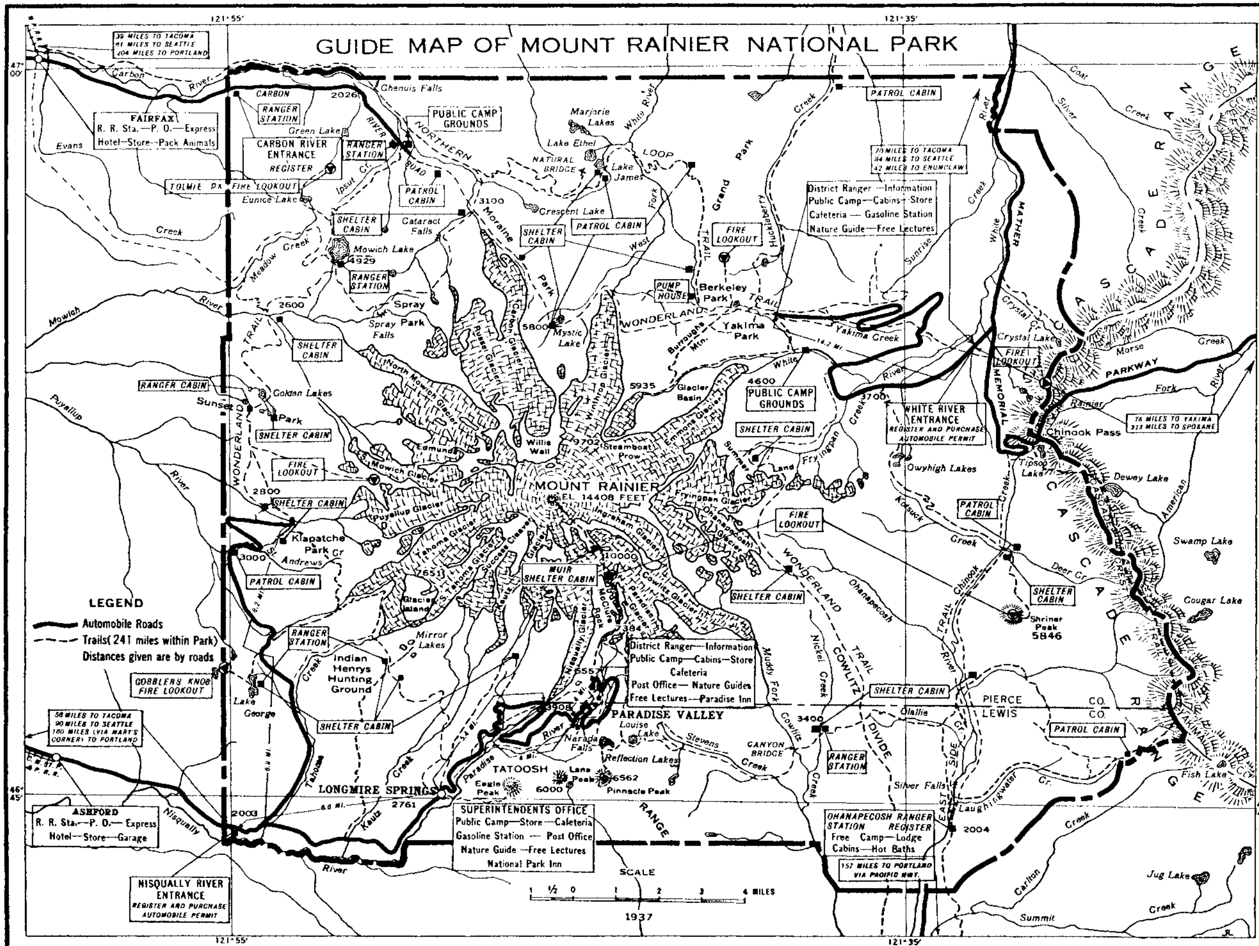

FIG. 1.—Guide map of Mount Rainier National Park (from the *Mount Rainier National Park Circular of General Information* [1937]). By permission of Dr. H. C. Bryant, assistant director, National Park Service, Washington, D.C.

tween October 1 and May 1, and a large portion of this moisture falls as snow.

Meteorological data are available for Longmire (2,760 ft.), Paradise Park (5,557 ft.), and the Carbon River entrance (1,716 ft.). The first two locations are on the south side of Mount Rainier National Park, while the latter is in the northwest corner of the area. However, owing to the very incomplete nature of the Carbon River records, these have not been included in the tabulations (Table 1).[12]

TABLE 1

Month	Average Monthly and Annual Precipitation		Average Monthly and Annual Snowfall		Average Monthly and Annual Temperature*		Highest Temperatures Recorded*		Lowest Temperatures Recorded*	
	Longmire	Paradise	Longmire	Paradise	Longmire	Paradise	Longmire	Paradise	Longmire	Paradise
January...	12.57	15.93	44.6	110.8	30.3	26.3	58	62	−9	−14
February..	7.97	9.28	30.1	64.5	32.0	27.2	59	58	−8	−12
March.....	8.06	10.67	33.8	96.7	35.2	27.9	73	66	9	0
April......	5.07	6.31	13.8	51.7	40.9	34.2	85	70	12	2
May......	4.01	4.97	2.5	23.3	47.7	40.8	95	88	21	14
June......	2.73	3.59	0.0	6.3	54.7	46.1	98	86	28	13
July.......	1.12	1.28	0.0	0.4	59.8	51.6	105	86	33	20
August....	1.73	2.97	0.0	Trace	60.6	50.7	99	100	35	24
September.	3.79	7.18	Trace	7.5	52.5	44.9	95	83	24	18
October...	7.89	9.79	1.1	21.4	46.4	40.6	88	79	17	2
November.	10.19	11.58	15.2	64.8	37.8	33.6	76	69	8	2
December .	13.05	15.41	28.8	101.6	31.6	27.4	60	60	−7	−20
Annual.	78.25	100.14	178.9	578.5	44.1	38.0	......	......	......	......
Length of record...	1909–36	1918–36	1912–36	1920–36	1913–36	1921–36	1913–36	1921–36	1913–36	1921–36

* All temperatures are in Fahrenheit.

METHODS USED IN MEASURING THE RECESSION OF THE GLACIERS IN MOUNT RAINIER NATIONAL PARK

The determination of the actual end of the ice in the case of practically all the glaciers on Mount Rainier is a difficult matter. The inclination of the ice at the termini, the varying widths of the

[12] L. C. Fisher, *Climatic Summary of the United States*, Sec. I: *Western Washington* (U.S. Weather Bureau, 1936); *Climatological Data, Washington Section* (U.S. Weather Bureau, monthly climatological review, 1931–36, incl.).

termini, the presence of ice caves or ice "lips," the character and depth of the morainal material, the irregular shapes of the termini, and numerous other factors all contribute to the confusion in determining the actual end of the glaciers in question. The abundance of morainal material in the case of the Emmons Glacier and the South Tahoma Glacier made it particularly difficult to determine the exact extent of the ice in those instances.

Because of these confusing factors, the true terminus of each glacier measured has been considered as that point in the ice from which the main stream emerged.[13] This method, of course, causes some inconsistency in the data from year to year, as in the case of the Emmons Glacier, but it is felt that over a period of years the average annual recession figure for each glacier will be more nearly accurate than if miscellaneous or poorly defined points were selected.

The method by which recession is measured differs with the glacier in question. In the case of the Emmons Glacier measurements are made from points on a base line located by instrumental survey. Whenever possible, rocks which have the appearance of permanency are also marked, and check measurements are made from these. Large rocks below the Nisqually, South Tahoma, and Stevens glaciers are marked annually, and recession is tabulated from measurements made from these. In the case of the Carbon Glacier a large rock outcrop over 700 feet below the terminus was selected in 1932 after several unsuccessful attempts had been made to locate a permanent marker. In addition, a rock on the moraine below the ice face was marked in 1936 for use in future check data. Three points along the broad front of the Paradise Glacier have been marked, and measurements have been made from these each year.

NISQUALLY GLACIER

Recession data have been taken annually on the Nisqually Glacier since 1918, and, in addition, the position of its terminus has been located by authentic historical records and old photos for three periods previous to 1918, one as far back as 1857.[14]

[13] The Paradise Glacier, because of individual conditions, is an exception to this rule.

[14] In July, 1857, Lieutenant A. V. Kautz, U.S.A., with several companions made the first known attempt to ascend Mount Rainier. This party approached their objective

Table 2 indicates that the rate of recession in the case of the Nisqually Glacier has been much greater since 1918 than was the

FIG. 2.—Terminus of the Nisqually Glacier in 1937, as viewed from the bridge which spans the Nisqually River; the approximate location of the terminus of the Nisqually Glacier in 1885.

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from Fort Steilacoom on Puget Sound by way of the Nisqually River valley. At its upper end they encountered a wall of ice which was the terminus of the glacier. In his diary of the trip Kautz states: ". . . . Where the glacier terminated, the immense vein of granite that was visible on both sides seemed to form a narrow throat to the great ravine, which is much wider both above and below" (E. S. Meany, *Mount Rainier—a Record of Exploration* [New York: Macmillan Co., 1916], pp. 72–93).

When annual recession measurements were initiated in 1918, this place was identified 760 feet below the present bridge which spans the Nisqually River.

According to Len Longmire, grandson of James Longmire who established a mineral claim about the springs near the present park headquarters and village of Longmire in 1883, the glacier terminated in 1885 at a point about where the present bridge crosses the river. He states, further, that the terminus occupied a position about 140 feet above this site in 1892 and that members of the Longmire family were the first to notice that this glacier was receding. Accustomed to obtaining ice from the terminus of the glacier for the purpose of preserving perishable foods, they observed that it was necessary each year to make longer trips in order to obtain ice. In consequence, the position of the terminus became identified with near-by topographical features, making it possible, when recession measurements were begun in 1918, to identify the approximate position of the end of the Nisqually Glacier fairly accurately for 1885 and 1892.

case during any previous period of years for which recession records are available. This may be summarized as in Table 3.

EMMONS GLACIER

Recession measurements on the Emmons Glacier, largest on Mount Rainier, were initiated on September 22, 1930. A base line,

TABLE 2

TABULATION OF RECESSION DATA

Period	Feet	Period	Feet
1857–85	760	1926–27	43
1885–92	140	1927–28	89
1892–1918	1310	1928–29	52
1918–19	59	1929–30	118
1919–20	46	1930–31	49
1920–21	106	1931–32	50
1921–22	67	1932–33	44
1922–23	44	1933–34	155
1923–24	83	1934–35	54
1924–25	73	1935–36	65
1925–26	86	1936–37	55

TABLE 3

AVERAGE ANNUAL RATE OF RECESSION

Period	Feet
1857–1937	44.3
1857–85	27.1
1885–92	20.0
1892–1918	50.3
1918–37	70.4

bearing N.20° W., was surveyed from a point established on the south side of the White River. This line crossed the glacier above the place where the stream emerged from the ice, and thus, in accordance with the policy of considering the point on the ice from which the main stream emerged as the true terminus, the distance from the base line to the ice in 1930 was nil.

The use of a base line was deemed advisable in this case, for no rocks of sufficient size to insure stability were to be found in the river bed below the ice.[15] The terminus presented the appearance of a wide, irregular, concave curve with a broad lobe of moraine-covered ice extending downstream on each side of the White River, which emerged from the ice near the middle of this curve. It was thus apparent that it would be difficult to compute the recession with any degree of accuracy other than by means of measurements from a base line.

FIG. 3.—Terminus of the Emmons Glacier in 1937, as viewed from a point on the trail overlooking the ice.

In the fall of 1931 it was obvious that the recession for the year 1930–31, as well as the year following, would have little significance if considered individually. At this time the ice face presented a very uneven appearance. A deep and very narrow cleft had formed in the vicinity of the stream, with lobes of ice extending downstream on both sides of the White River almost to the base line.

[15] In later years when such rocks presented themselves, they were marked so that check data could be taken from them. Few of the rocks so marked were able to resist the flood periods of the White River until 1936. Consequently, most of the recession data have been derived from measurements made from the ice face to points on the base line.

In the fall of 1932 the stream issued not from a point in the ice similar to its position of the previous year but from the side of the left lobe. In the fall of 1933 the course of the stream had changed again and was once more emerging from the ice at a point comparable to its position in 1932. The apparent "advance" of the glacier recorded for the year 1933–34 was, of course, due to the change in the position of the stream rather than the downward movement of the ice. Changes at the terminus have not been as

TABLE 4

TABULATION OF RECESSION DATA

Sept. 22, 1930	Base line surveyed from the permanent marker
1930–31	Recession of 142 feet (no supplementary measurement)
1931–32	Recession of 2.5 feet (on supplementary measurement a recession of 19 feet)
1932–33	Recession of 48.5 feet (on supplementary measurements a recession of 32 feet)
1933–34	"Advance" of 1.5 feet (due to the change in the position of the stream rather than any downward movement of the glaciers; on supplementary measurements a recession of 132 feet)
1934–35	Recession of 67 feet (on supplementary measurements a recession of 30 feet)
1935–36	Recession of 193 feet (on supplementary measurements a recession of 100 feet)
1936–37	Recession of 10 feet (on supplementary measurements a recession of 16 feet)

radical since 1934, but the examples noted will indicate why the use of a base line was necessary for accurate computations.

In addition to recording measurements from the base line to the point in the ice from which the stream emerged, supplementary data were also taken. These data were computed from measurements made from the base line, or rocks in some cases, to other points on the ice face (Table 4).

The recession of the Emmons Glacier since 1930 may be computed in four different ways from Table 4. On the basis of those recession figures, which consider the point on the ice face from which the stream emerges as the true terminus, the average annual recession is 65.9 feet. On the basis of the supplementary measurements, the average annual recession is 54.8 feet. If the recession indicated by each method is averaged each year, and the average annual recession computed from these yearly average figures, the average annual recession is 54 feet. The average of the three results indicates an average annual recession of 58.2 feet.

CARBON GLACIER

The initial attempt to establish a permanent point from which to compute annual recession data on this glacier was made on Sep-

FIG. 4.—Terminus of the Carbon Glacier in 1937, as viewed from the marker from which recession is measured, 870 feet from the ice.

tember 22, 1930. This original marker, as was a second point established in the following fall, was lost.

The third attempt was made on October 1, 1932. A large rock outcrop on the southwest side of the Carbon River 723 feet from the terminus was selected and appropriately marked. This marker has persisted since that time, and the recession of the Carbon Glacier has been computed from that point annually. In addition, a second marker, known as point X, was established nearer the ice face on

September 18, 1936. Check data have been taken annually since that time. Table 5 indicates that the average annual recession of the Carbon Glacier since 1932 is 29.4 feet.

TABLE 5

TABULATION OF RECESSION DATA

Sept. 22, 1930	Original marker established
1930–31	Original marker not found; second marker established
1931–32	Second marker not found; third marker established
1932–33	Recession of 12 feet (marker 735 feet from the terminus)
1933–34	Recession of 29 feet (marker 764 feet from the terminus)
1934–35	Recession of 24 feet (marker 788 feet from the terminus)
1935–36	Recession of 62 feet (marker 850 feet from the terminus) Point *X* established 327 feet from the terminus for use in future check measurements
1936–37	Recession of 20 feet (marker 870 feet from the terminus) Point *X* 347 feet from the terminus

SOUTH TAHOMA GLACIER

Recession studies were initiated at the terminus of this glacier on October 1, 1931, when a large rock 140 feet from the terminus was marked.

The ice face in question is actually the combined mass of the lower part of the South Tahoma Glacier and an arm of the Tahoma Glacier, these two merging below Glacier Island (see map, Fig. 1). The former occupies the canyon to the southeast of Glacier Island, while the latter is found on the west side. Eventually these two bodies of ice will separate and retreat up their own specific canyons.

In the light of recent observations, the retreat of this combined ice face is not proceeding in an orderly and uniform manner. Owing to the irregular melting of the ice, it is unlikely that this retreat will bring about a clear-cut, simultaneous division of the two ice fields when the apex of Glacier Island is reached. Instead, factors which influence the melting of the ice may cause either the narrower South Tahoma Glacier or the more exposed arm of the Tahoma Glacier to be pinched off before that time. While this will undoubtedly complicate matters relative to the recession measurements in the future, the more consistent of the two ice streams, or both, will be measured when a decision as to which glacier to follow has to be made.

On September 7, 1934, in anticipation of a change in the course of the stream which would cause it to emerge from a different point in the ice, a second marker was established. This marker, known as point *B*, was 142 feet from the ice. By 1935 the anticipated change in the stream had occurred, and the point from which the stream

FIG. 5.—Terminus of the South Tahoma Glacier in 1937, as viewed from the "established photo point" on the river bar.

emerged in former years was entirely covered with morainal debris which had lodged at the base of a high ice face which crowned that point. In the fall of 1936 and 1937 this ice face was smaller and the accumulation of debris larger. The stream has since continued to issue from the same point in the ice face as in 1935.

On September 25, 1936, a third marker was established below another ice face which had taken form some distance from points *A* and *B*. This marker was not found in the fall of 1937. However, a new marker, 77 feet from the ice, was established for future recession measurements at this place. Table 6 indicates that the average annual recession of the South Tahoma Glacier is 50 feet from point *A*, and 30.6 feet from point *B*. Considering the point from which the stream emerges as the true terminus (in this case the tabulations from point *A* are selected for 1932, 1933, and 1934, while tabulations from point *B* are used for 1935, 1936, and 1937), the average annual recession is 35.8 feet. An average of the three results, noted above, indicates an average annual recession of 38.8 feet per year.

TABLE 6

TABULATION OF RECESSION DATA

Oct. 1, 1931	Original marker placed 140 feet from the terminus
1931–32	Recession of 37 feet (marker 177 feet from the terminus)
1932–33	Recession of 13 feet (marker 190 feet from the terminus)
1933–34	Recession of 73 feet (marker 263 feet from the terminus) Point *B* established 142 feet from the ice
1934–35	Point *A*—recession of 61 feet (marker 324 feet from the ice) Point *B*—recession of 42 feet (marker 184 feet from the terminus)
1935–36	Point *A*—recession of 66 feet (marker 390 feet from the ice) Point *B*—recession of 37 feet (marker 221 feet from the terminus) Point *C*—established 107 feet from the ice
1936–37	Point *A*—recession not computed; point on ice face too indefinite for accuracy Point *B*—recession of 13 feet (marker 234 feet from the terminus) Point *C*—marker established in 1936 not found; new point established 77 feet from the ice

PARADISE GLACIER

To augment recession studies made on the four active valley glaciers (Nisqually, Emmons, Carbon, and South Tahoma), similar measurements have been made at the termini of two intermediate glacierets, known as the Paradise and Stevens glaciers. The Paradise Glacier is the better known and more accessible of the two, and on September 23, 1932, three prominent rocks in front of its broad face were selected and appropriately marked as points *A*, *B*, and *C*. Measurements have been made annually, whenever possible, from each of these points to the nearest ice.

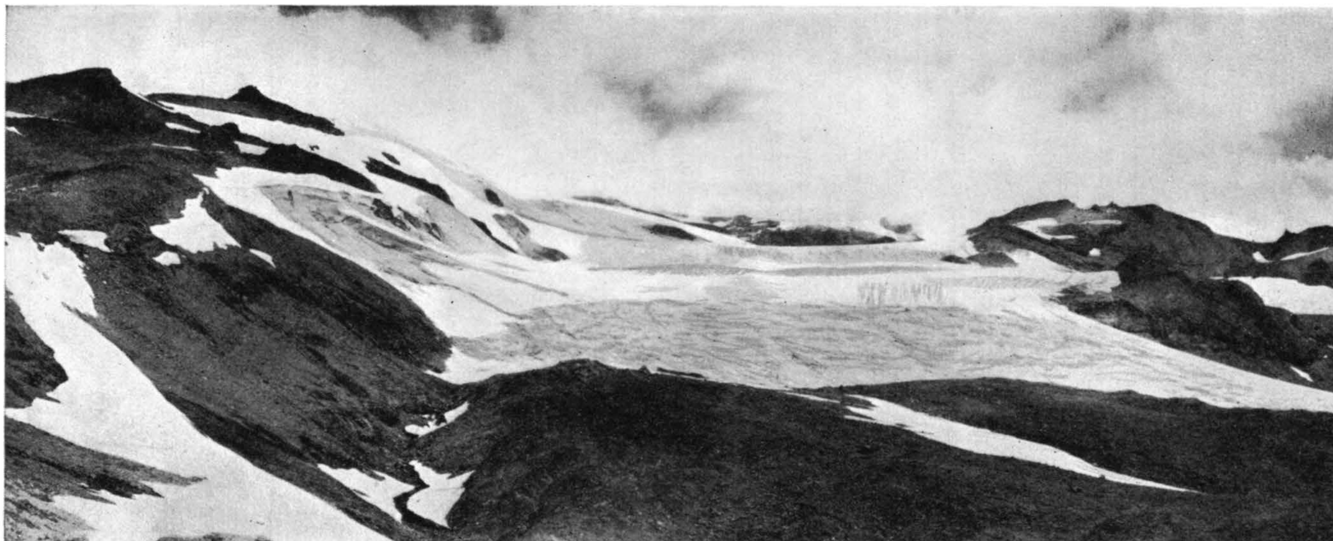

FIG. 6.—Paradise Glacier in 1937, as viewed from the "established photo point" on the ridge overlooking the ice. Points *A*, *B*, and *C* are located along the front of the glacier. The tongue of ice to the right is the Stevens Glacier.

Actually, the terms "Paradise Glacier" and "Stevens Glacier" are merely names given to lobes of a parent ice field. The lobe known as the Paradise Glacier originally extended down the extreme upper portion of the Paradise River Valley; that known as the Stevens Glacier extends down another valley and gives rise to Stevens Creek.

TABLE 7

TABULATION OF RECESSION DATA

Year	Point	Distance from the Marker to the Ice (in Feet)	Recession Noted (in Feet)
1932	*A*	13	Points established
	B	38	
	C	45	
1932–33	*A*	Covered with snow	Unknown
	B	43	5
	C	52	7
1933–34	*A*	20	7 (since 1932)
	B	78.5	35.5
	C	76	24
1934–35	*A*	Covered with snow	Unknown
	B	102	23.5
	C	Covered with snow	Unknown
1935–36	*A*	92	72 (since 1934)
	B	162	60
	C	110	34 (since 1934)
1936–37	*A*	Edge of ice covered with snow	Unknown
	B	190	28
	C	Edge of ice covered with snow	Unknown

In recent years the Paradise Glacier has receded to a point where it represents little more than a flank of the parent ice field. The amount of water which flows from it has been materially reduced, and the spectacular ice caves of a few years ago are no longer extant.

From Table 7 it is seen that the average annual recession of the Paradise Glacier is 19.7 feet from point *A*, 30.4 feet from point *B*, and 16.2 feet from point *C*. The average annual recession of the entire ice front, as computed from the averages of the three points noted, is 22.1 feet.

FIG. 7.—Terminus of the Stevens Glacier in 1937, as viewed from the point which marked the edge of the ice in 1935.

STEVENS GLACIER

Recession measurements on this glacier were initiated on September 5, 1934, when a point was established upon a prominent rock 52 feet from the end of the ice. In the fall of 1935 it was impossible to locate this original marker as it had in all probability been washed away sometime during the intervening period. A second point was established upon a solid, stationary rock face that was just emerging from the ice at the terminus.

TABLE 8

TABULATION OF RECESSION DATA

Sept., 1934	Original marker established
1934–35	Original marker not located; second point established
1935–36	Recession of 146 feet
1936–37	Recession of 187 feet

Recession data in the case of the Stevens Glacier are still scanty, for only two years have elapsed since the permanent marker was established. In addition, the extreme recession indicated by Table 8 is misleading, as the glacier terminates in a long tongue of ice that extends some distance from the main body. The very rapid melting of this ice tongue is, naturally, reflected in the recession data. Such an apparently excessive annual recession will be the rule for at least two more years when, following the disintegration of the ice tongue, a more normal retreat will become evident.