Compliments of François E. Matthes

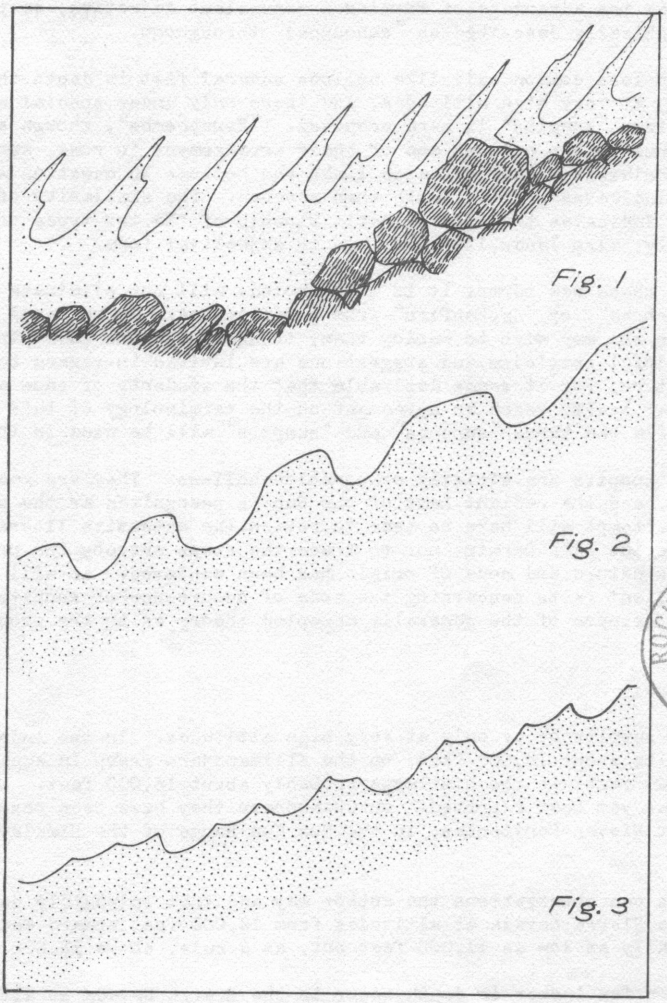
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ABLATION OF SNOW-FIELDS AT HIGH ALTITUDES BY RADIANT SOLAR HEAT

François E. Matthes

Snow-fields and the so-called névés of glaciers on lofty mountains often present a peculiar, honeycombed appearance, the surface being pitted with deep cell-like hollows a foot or two feet in diameter and from a few inches to several feet in depth. When typically developed these hollows are closely spaced, the divides between them consisting merely of attenuated blades and pinnacles of hard, granular snow (Fig. 1). The hollows are alined roughly in rows and sunk at a uniform, high angle, all in the same direction.

The pinnacles have come to be known in the literature by the picturesque name of "nieve penitente"--a contraction from "nieve de los penitentes", which is the popular



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Fig. 1--Sectional view of maturely developed sunpits about 2 feet in depth (drawn from a photograph taken in the Sierra Nevada at an altitude of 13,000 feet)

Fig. 2--Sectional view of sunpits in an early stage of development; intermediate portions of snow-field still unconsumed

Fig. 3--Typical suncups such as occur in the Sierra Nevada at altitudes above 10,000 feet; these are mature forms due to long-continued ablation, yet the hollows are only a few inches deep

name for them in the Andes of Argentina and means snow resembling penitent monks. The Germans have translated this to "Büsserschnee", but they also employ the term "Zackenfirn." None of these foreign terms has found, nor is likely to find, general acceptance in this country, all of them being for English-speaking people awkward to pronounce. Besides, they are unwieldy and ill adapted for technical use. It seems in order, therefore, to seek an appropriate and convenient English term.

In this quest for a new term, however, it is to be borne in mind that the blades and pinnacles, though conspicuous to the eye, are merely secondary, residual features. The hollows are genetically the primary and significant forms. They develop each as an independent unit, often at distances of several feet from one another (Fig. 2), and it is for them that a new term is most urgently needed. In a previous paper the author tentatively suggested the terms "suncups" and "honeycombs" (F. E. Matthes, Mount Rainier and its glaciers, Dep. Interior, Washington, D. C., pp. 17-18, 1914). Here he proposes more formally the term "suncups" for the shallow hollows, only a few inches in depth (Figs. 2 and 3), that occur in great abundance on the lower snowfields of high mountains and occasionally at moderate elevations, as low even as sea-level. The term not only is in a measure expressive of the smoothly concave form of these hollows but links them with the source of energy by which they are called forth. In addition it has the advantage of forming a convenient adjective, so that a snowfield may be graphically described as "suncupped" throughout.

For the much less common cell-like hollows several feet in depth that develop from suncups only at very high altitudes, and there only under special weather-conditions, the term "sunpits" is here proposed. ("Honeycombs", though suggestive of the cell-like forms of the hollows and of their arrangement in rows, seems less appropriate nevertheless.) "Sunpits" also links the hollows in question with the rays of the Sun, but indicates greater depth than suncups. The similarity of the two terms, moreover, indicates the close genetic kinship of the two types of forms. "Sunpits", finally, also lends itself to use in adjectival form.

Adoption of these new terms, it is to be noted, will not eliminate "nieve penitente", "Büsserschnee", or "Zackenfirn" from possible use. These terms remain available, for any one who may wish to employ them, to designate the snow-pinnacles between the sunpits. Helpful criticism and suggestions are invited in regard to these matters of nomenclature, for it seems desirable that the students of snow and of glaciers, in this country at least, reach an agreement on the terminology of this part of their science. Meanwhile the terms "suncups" and "sunpits" will be used in this paper.

Suncups and sunpits are strictly evaporation-hollows. They are generally conceded to be such, and the radiant heat of the Sun is recognized as the agent that produces them. No attempt will here be made to review the extensive literature on the subject, which begins with Darwin, nor to trace the steps whereby the present understanding of their nature and mode of origin has been achieved. It will suffice to enumerate the salient facts concerning the mode of occurrence of sunpits and suncups, and to state the essence of the generally accepted theory as to the process of their evolution.

The facts are:

(1) Typical sunpits occur only at very high altitudes. In the Andes their lower limit appears to be about 12,000 feet; on the Kilimandjaro group in equatorial Africa it is about 15,000 feet; in the Himalayas probably about 16,000 feet. No upper limit to their range has yet been reported. On Chimborazo they have been observed at 18,000 feet and on Mount Nieves Penitentes, in the Nun Kun Range of the Himalayas, at above 19,000 feet.

(2) From his own observations the author may add that splendidly developed sunpits occur in the Sierra Nevada at altitudes from 12,000 feet upward and on Mount Rainier occasionally as low as 11,000 feet but, as a rule, above 12,000 feet.

(3) Suncups a few inches in depth occur in the Sierra Nevada at altitudes as low as 10,000 feet and on the lower slopes of Mount Rainier down to about 8000 feet.

(4) Typical sunpits develop only on mountains in low and moderate latitudes. They have not been observed (as far as known) in the Rockies and Selkirks of Canada, nor on

the mountains of Alaska. They are absent in the polar regions. On the other hand, they attain greatest depth near the equator. In the Andes depths of 15 to 18 feet have been measured.

(5) Typical sunpits develop only on mountains that have a dry summer climate and that are exposed to strong insolation for prolonged periods. They are unknown in the European Alps, which have a prevailingly humid climate, but shallow suncups are produced there occasionally.

[The frequent occurrence of well-developed sunpits on Mount Rainier is of peculiar interest in view of the high latitude of that peak--46° 50'--and also in view of its reputedly humid climate. The fact is, however, that the summit of Mount Rainier rises well above the zone of maximum cloudiness and precipitation, and often has from five to ten consecutive days of sunshine in summer.]

(6) The angle at which the blades and pinnacles of snow between the sunpits lean corresponds to the elevation of the Sun at midday. In the Northern Hemisphere they lean toward the south; in the Southern Hemisphere they lean toward the north. At the equator they stand vertical.

(7) Sunpits and suncups attain typical forms only in clean snow. Rock fragments and wind-blown dust interfere with their orderly development and tend to produce irregular forms. Sunpits and suncups are not to be confused with "dust-wells" or cryoconite basins and cavities.

(8) Sunpits and suncups are produced without visible liberation of melt-water and are at all times dry. Melt-water, if it accumulates at the bottom of a hollow, retards and may frustrate entirely its further development by refreezing into a cake of hard ice.

Theory of development--It is generally agreed that sunpits and suncups are produced by the radiant heat of the Sun. It transforms the snow directly into water-vapor, which is absorbed by the dry air as fast as formed. A part of the water-vapor, nevertheless, is sublimated on the sides of the hollows, and as a consequence these are converted by progressive recrystallization into firm, granular névé.

The inception of suncups and sunpits is traceable to the original unevennesses of the snow-field. The inevitable effect of the Sun's rays is to accentuate the depth of any initial concavity, however slight and by whatever cause produced. That part of the concave surface upon which they impinge at right-angles at midday--when they are strongest--will waste away more rapidly than any other part, the amount of solar heat received per unit of surface varying as the cosine of the angle of incidence (Figs. 4 and 5). Moreover, there will be a concentration of solar heat at the bottom of each pit as a result of reflection from the sides. Thus each pit will be deepened more rapidly than widened, and always in the direction of the Sun's rays at midday.

The deeper the pit grows, the more nearly parallel to the direction of strongest insolation its north and south walls will become, and the less ablation these will suffer. The west wall, meanwhile, suffers mild but increasingly intense ablation during the morning hours, and the east wall suffers diminishing ablation during the afternoon hours, and so the hollow tends to become elongate in east-west direction. If the period of dry, sunny weather lasts long enough the west and east walls will be partly destroyed, and adjacent pits will finally coalesce, so as to form an east-west trench or furrow with uneven bottom.

The intimate details of the process need not be pursued further here, for they are of little consequence to either the meteorologist or the hydrologist. But one point deserves more emphasis than it has been given hitherto, namely, that low air-temperatures, at or below the freezing-point, are indispensable for the typical development of sunpits. In other words, it is essential for best results that atmospheric heat shall have no part in the ablation of the snow-mass.

The rays of the Sun, it is to be borne in mind, impinge at midday normally upon the bottoms of the pits and likewise upon the crests of the partitions (Fig. 5). They act with equal intensity on both. What is more, they shine all day long, from one

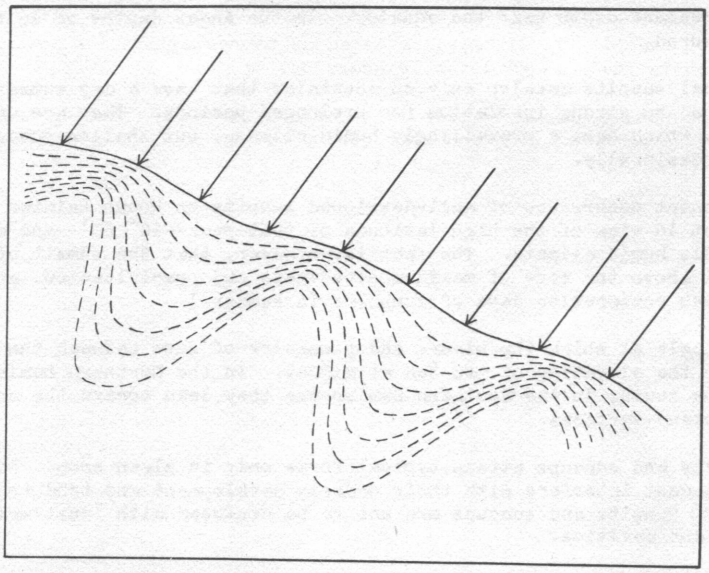


Fig. 4--Sectional view showing development of deep sunpits from shallow concavities in surface of snow-field; arrows indicate direction of Sun's rays at noon; curves are drawn empirically only

direction or another, upon the upper parts of the partitions, but only for a few hours in the middle of the day upon the bottoms of the pits. Again, the partitions are inherently much more vulnerable to insolation than the bottoms of the pits, because they have a much greater area of exposed surface per unit of volume than the latter. Especially is this so when they are reduced to attenuated blades and pinnacles such as are shown in Figure 1. Yet the pits are lowered more rapidly from day to day than the partitions. There must then be some additional agency or agencies that operate either to accelerate ablation in the pits or to retard it on the partitions, or to do both.

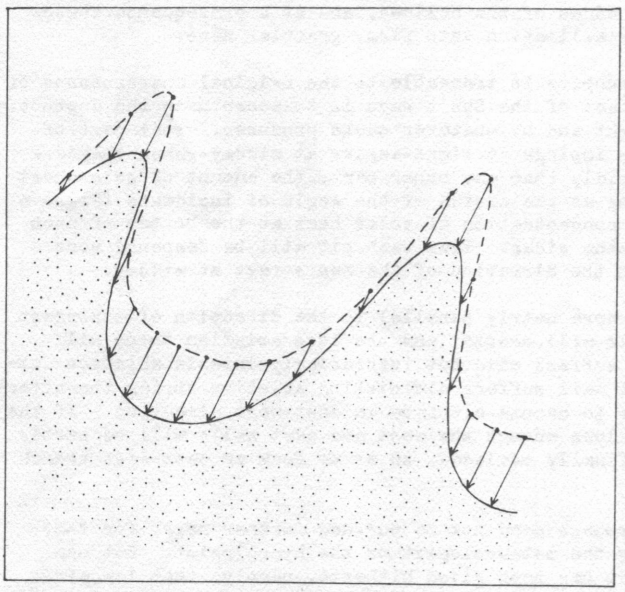


Fig. 5--Idealized sectional view of a sunpit and adjoining partitions; arrows indicate direction of Sun's rays at noon, their plotted lengths indicating the relative intensity of insolation at each point, which is proportional to the cosine of the angle of incidence (Note that the maxima at the bottom of the pit and on the tops of the partitions are equal)

The concentration of solar heat at the bottom of each pit by reflection from the walls doubtless is a factor, but the excess of heat thus created cannot be considerable in view of the great capacity that snow has for absorbing radiant solar heat (N. N. Kalitin, Radiant properties of a snow-cover, Bull. Observ. Géophys. Central, Leningrad, Nos. 1-2, pp. 9-18, 1931). It is not likely, therefore, that this slight concentration of solar heat would alone account for the rapid deepening of the pits.

The hardening of the partitions by progressive recrystallization doubtless operates to retard their reduction, but this cannot be a potent factor either, for the snow at the bottom of the pits is likewise hardened by recrystallization whenever it is in shadow--and that is the case at least 18 hours out of every 24.

A much more potent agency is seen in light breezes with freezing temperatures that waft across the snow-fields and refrigerate the tops of the partitions while affecting but slightly the sheltered hollows. Such chilling breezes, the author is inclined to believe, do much to lengthen the life of the partitions. Strong gales, on the contrary, are probably unfavorable, for they accelerate evaporation from the partitions and refrigerate the hollows as well as the partitions. It is, as a matter of observation, preeminently during periods of high barometer, characterized by cold, clear, dry weather, and light breezes, that sunpits attain their most perfect development.

It is, then, the unusual combination of intense solar heat and freezing air-temperatures, even at midday, coupled with low humidity, that permits sunpits to attain great depth. Obviously this combination of conditions can obtain only at very high altitudes. At lower levels, where the air-temperature mounts daily appreciably above the freezing-point, the partitions are not sufficiently refrigerated to maintain any considerable height. At the lower levels, moreover, solar heat is less intense, and its effect is more readily offset by rising air-temperature and rising humidity. For these reasons no sunpits, but only shallow suncups, are produced. And at still lower levels atmospheric ablation becomes preponderant and the snow-fields melt down evenly.

On a peak such as Mount Rainier, whose snowy robe in early summer has an altitude range of fully 10,000 feet (from 14,400 to about 4000 feet) the gradation from deep sunpits at the top to shallowest dimples below is often impressively displayed. Above 13,000 feet the pits may be two feet deep, offering an exasperating impediment to the mountaineer; at 12,000 feet they are likely to be only one foot deep; at 10,000 feet they degenerate into suncups half a foot in depth and so broadly open as to be an aid rather than an impediment to the climber; in the vicinity of 9000 feet the hollows are only a few inches deep, and at 8000 feet they are mere dimples that do not interfere with the pleasurable glissades of tourists.

In conclusion, a word about the hydrologic significance of sunpits and suncups in snow-fields on high mountains. As already stated, these hollows are produced without the liberation of melt-water. Indeed, on his visits to the central High Sierra the author has been impressed again and again by the fact that the strongly sunpitted snow-fields above 12,000 feet waste away during the summer without contributing a drop of water to the streams in the valleys below. Even when the individual pits finally reach down to the rocks of the mountain side, so that only a skeleton of snow-ridges and snow-pinnacles remains, no running water is in sight. Below 12,000 feet, and as far down as about 11,000 feet (near the timber line), the suncupped snow-fields yield a little running water, depending upon exposure. Enough melt-water may be produced in the middle of the day to drench the mantle of frost-riven rock fragments that covers the mountain side, and to promote the processes of nivation and solifluction, but no rivulets capable of eroding channels are to be seen, and the mountain-side remains unfurrowed by ravines.

It follows that these upper snow-fields are in no sense the sources of streams and are to be excluded from any estimates of runoff based on snow-surveys. How much of an area may be involved in a great mountain range such as the Sierra Nevada it is as yet impossible to estimate. The aggregate may run up into some hundreds of square miles, or it may be considerably less. Special studies for the purpose of obtaining more accurate information on this point are recommended.

It follows, further, that the lofty névé fields at the heads of glaciers--as, for instance, those on the broad summit of Mount Rainier--contribute nothing, from their surfaces at least, to the runoff from the glaciers. From their basal layers small quantities of water may possibly be released by the warmth of the mountain and by pressure melting, but for practical purposes these quantities are probably negligible. It is from the lower portions of the glaciers that the great floods of melt-water in summer are derived. On the glaciers of Mount Rainier surficial melting in sufficient

quantities to produce rills and rivulets on the ice does not extend above an altitude of about 7500 feet. On warm days these streamlets form miniature river-systems, with miniature waterfalls, lakes, and canyons cut in the ice. They are truly impressive for the volume of water they carry off, but far more impressive, if one stops to consider it, is the fact that from this low level upward to the summit of the peak--through an altitude range of some 7000 feet--the snow and névé extend with dimpled, suncupped, sunpitted surfaces that are perpetually dry.

U. S. Geological Survey,
Washington, D. C.

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EVAPORATION AND RUNOFF FROM SNOW IN THE ALPINE ZONE OF OUR WESTERN MOUNTAINS

FRANÇOIS E. MATTHES

(Summary)

In this informal paper the processes of snow-wastage at high altitudes were discussed and a number of slides illustrating suncups and sunpits in different stages of development were shown. It was stressed that these features are peculiar to the region above the timber-line, which biologists term the Alpine, or Arctic-Alpine, Zone. That regions is, as a matter of fact, primarily and fundamentally a physiographic zone distinct from all other physiographic zones at lower levels by reason of an unusual combination of climatic, hydrologic, and geologic factors.

Owing to low air-temperatures all the year round (freezing temperatures being frequent even in midsummer) but a small proportion of the snow-pack in the Alpine Zone is transformed into melt-water. On the other hand, because of the intensity of radiant solar heat at high altitudes, wastage of snow by direct evaporation is very great. This is so especially on those of our western mountain ranges that have a relatively dry summer climate.

Radiant solar heat tends to accentuate the irregularities of the snow-surface, and if permitted to act without interference for several days in succession, produces shallow cup-shaped hollows (suncups). These under favorable conditions gradually deepen to roughly cylindrical pits several feet in depth (sunpits). The jagged pinnacles of crystalline snow that remain standing between the sunpits are the familiar nieve penitente described by explorers and mountaineers. Suncups and sunpits may be seen on our western mountains every summer; nieve penitente, on the other hand, are relatively rare.

The runoff from snow-fields in the Alpine Zone decreases markedly toward the higher levels. Above altitudes of 11,000 to 12,000 feet, according to latitude, melt-water is so scanty that it forms no channel-making streams or streamlets. Above 13,000 feet the snow-fields yield but small trickles that do not reach the valleys below. It follows that these upper snow-fields are in no sense the sources of streams and are to be excluded from any estimates of runoff based on snow-surveys.

U. S. Geological Survey,
Washington, D. C.

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REPORT OF COMMITTEE ON GLACIERS, 1937-38

François E. Matthes, Chairman

During the past year the Committee lost by resignation one member, R. H. Sargent, but gained another, Professor Wm. S. Cooper of the University of Minnesota, whose ecologic studies of the vegetation in Glacier Bay, southeastern Alaska, have shed new and valuable light on the past fluctuations of the vast glaciers of that unique area.

The Committee continues to be represented on the International Glacier Commission by the Chairman, who is titular member for the United States, and by Professor Wm. H. Hobbs, who is associate member. Both are also members of the International Commission of Snow, of which Professor J. E. Church is President.

Following is the Committee's report on the glaciers of the United States and Alaska for the 12-month period ending October, 1937.

Glaciers of Mount Baker

The Easton and Coleman glaciers on Mount Baker, noted for their unusually rapid recession during recent years, were again measured in 1937 by Herbert V. Strandberg and assisting members of the Mountaineers of Seattle, Washington. Both glaciers continue to recede but at a decidedly slower rate than previously.

Easton Glacier, situated on the south-southeast flank of the peak, receded 116 feet during the year ending September 26. This recession compares with 170 feet during the preceding year, and with 190 feet two years ago. The amount, moreover, falls considerably below the mean rate of 176 feet for the 28-year period ending 1936 (based upon the total recession from its position

in 1908, which is shown on the topographic map of the United States Geological Survey). It is much less, also, than the mean rate of 160 feet for a period of 26 years, based upon a photograph taken in 1910.

Coleman Glacier, situated on the cooler northwest side of the peak, on October 3, 1937, had receded 52 feet, as compared with a mean rate of 86 feet for a period of 26 years, based on a photograph taken in 1910.

This appreciable slowing up of the recession of the two glaciers, moreover, is paralleled in a general way by the diminution in discharge of the Skagit River, which drains this portion of the Cascade Mountains. The gaging records at Diablo Dam show, for the year ending September 1934, a mean of 5,945 cubic feet per second (a high for the 26-year period); for the year ending September 1935 a mean of 4,653 cubic feet per second; and for the year ending September 1936 a mean of 3,450 cubic feet per second.

As Mr. Strandberg points out, the record of glacier-measurements on Mount Baker is as yet too short to afford a reliable basis for comparisons; nevertheless, the data obtained so far justify the belief that in the course of time the recession-record, taken in coordination with the data of precipitation and runoff that are available for the mountain district, will come to have real value as an index of the trend of climatic fluctuations.

Glaciers of Mount Rainier

Measurements made by C. F. Brockman, Park Naturalist of Mount Rainier National Park, seem to indicate a general slowing up of the recession of its glaciers in 1937. Five of the six glaciers measured had receded considerably less than the mean rate for several years past. The sixth glacier had receded an excessive amount, but this was due to local and temporary conditions not representative of the mountain area as a whole.

Nisqually Glacier, on the south side of Mount Rainier, showed a recession of 55 feet, as compared with a mean of 70 feet for the 19-year period since 1918. Whether this reduction has any significance as being indicative of a definite trend, remains to be seen, for 12 times during that period the glacier's recession has fallen below the mean, and five times it has been under 50 feet. The mean is brought up by several years of excessive recessions, when the amount ranged from 80 to 155 feet. Nor are the years of high and of low recession so distributed as to indicate any definite trend.

The complete table of recession for the Nisqually Glacier was published in last year's report and will not again be given here, but a recapitulation of the means for the successive periods, which presumably are indicative of climatic fluctuations, does seem appropriate.

From 1857 to 1885 the mean annual recession was 27 feet. From 1885 to 1892 it was 20 feet. From 1892 to 1918 it was 50 feet, and from 1918 to 1937 it has been 70 feet. The general trend, therefore, has been definitely upward since 1892, and has more than trebled during the last 45 years.

The total recession of the Nisqually Glacier since 1918, when annual measurements were begun, is now 1,338 feet. The total recession since 1857, when the glacier was first sighted, is 3,548 feet. The glacier is, however, still 4-1/2 miles long.

As was demonstrated by the two detailed topographic surveys of its lower half made in 1931 and 1936, and comparison of them with the small-scale topographic map of the Park made in 1910, this shortening of the Nisqually Glacier has been attended by a corresponding reduction in thickness. In 21 years, from 1910 to 1931, the surface of the glacier was lowered by melting between 80 and 120 feet over a stretch of approximately 4,000 feet; and from 1931 to 1936 it was lowered an additional 40 to 80 feet over a stretch of 3,500 feet.

As a result of this loss in thickness the lower half of the glacier now presents a very different appearance from the one it had in 1910. An island of rock protrudes through the middle of the glacier at the 5,500-foot contour-line, where formerly there was a tumultuous ice-cascade bristling with tall, leaning séracs. In 1931 this rock-island was 500 feet broad and had a sloping face about 180 feet high; by 1936 it had developed to a width of 650 feet and a height of 280 feet.

About 1,800 feet lower down on the glacier, at the 5,200-foot contour-line, another rock-mass has become uncovered. In 1931 this had the form of an island 700 feet long and 200 feet

broad, situated not far from the eastern margin of the glacier, but by 1936 it had become a rocky platform with sloping front, projecting from the eastern wall of the canyon. Opposite it the glacier has lost nearly 700 feet in width and is now only 1,100 feet wide.

This marked reduction in thickness and in volume, however, appears to be strictly limited to the lower half of the Nisqually Glacier. From the 5,700-foot contour-line (at the head of the first island mentioned) upward the surface of the glacier is no lower than it was in 1931 and in 1910, but, if anything, somewhat higher.

The detailed surveys of the lower Nisqually, it should be repeated here, were made by the Water Resources Branch of the United States Geological Survey in cooperation with the Department of Public Utilities of the City of Tacoma, the National Park Service, and the Bureau of Public Roads. The plane-table maps were made on the scale of 1:4800, with 20-foot contour-intervals. The plan is to repeat these surveys every fifth year for the purpose of determining the loss in volume sustained by the glacier. The earlier topographic map of Mount Rainier National Park was made by the Topographic Branch of the Geological Survey in 1910 and 1911, on the scale of 1:62,500, with 100-foot contour-intervals.

Emmons Glacier, the largest glacier, situated on the northeast side of Mount Rainier, had receded only 10 feet in 1937. As usual, Mr. Brockman made his measurements to the ice at the point of effluence of the stream, adding, however, a supplementary measurement to the approximate point of effluence of the year before. The latter measurement indicated a recession of 16 feet. The comparable figures in 1936 were 193 feet and 100 feet; and the means of the two sets of measurements for the period 1930 to 1937 were 66 feet and 55 feet, respectively.

While the recession of the Emmons Glacier is never capable of accurate determination because of the vast accumulations of morainal material that mantle its terminus, there can be no doubt that the recession in 1937 was far less than in previous years.

Carbon Glacier, situated on the north-northwest side of the peak, ensconced in a steep-walled, shady canyon, was found to have receded 20 feet, as compared with 62 feet in 1936, and as compared with a mean annual recession of 29 feet for the period 1932 to 1937.

South Tahoma Glacier, situated on the southwest side of the peak and confluent with the southern lobe of the Tahoma Glacier, in 1937 had receded only 13 feet at point B, as compared with 37 feet in 1936. Point A, which receded 66 feet in 1937, was found completely obliterated. At point B the mean annual recession since 1934 is 31 feet; at point A the mean annual recession since 1931 is 50 feet.

Paradise and Stevens glaciers, heretofore listed separately, are really but two lobes of one and the same ice-mass. The Paradise Lobe has now receded so far that it is little more than the southern flank of the parent mass, while the Stevens Lobe remains prominent and now may be regarded as the real terminus. As a result of these changes the famous ice-cave under the Paradise Lobe, which was formerly visited by many tourists, has ceased to exist, and the Paradise River, and the Sluiskin Falls by which that stream descends into Paradise Valley, have suffered appreciable losses in volume.

Recession of the Paradise Lobe has usually been measured at three points, A, B, and C. Of these only B was identifiable in 1937, the other two remaining covered with snow. The recession at point B amounted to 28 feet, as compared with 60 feet in 1936, and with a mean of 30 feet for a 5-year period. The total recession at point B since 1932, when measurements were begun, is 124 feet.

The Stevens Lobe is wasting away at a much more rapid rate than the Paradise Lobe, chiefly owing to its narrow, tapering form, which has a large melting surface per unit of volume. The recession, measured in 1937, amounted to not less than 187 feet, as compared with 146 feet in 1936. As Mr. Brockman points out in his report, the rate of recession doubtless will come down to a more nearly normal figure when the narrow ice-tongue has melted away.

The Paradise and Stevens lobes are of peculiar interest because the ice-mass of which they form part is merely a small secondary glacier lying on a gently sloping platform between the deep canyons of two primary glaciers--the Nisqually and the Cowlitz. It is only 1-3/4 miles long, heads in névé fields at altitudes near 8,000 feet, fully 2,000 feet below the general level at which the main cirque glaciers originate, and has a southerly exposure. It is nearly stagnant, and as a consequence the losses by melting at its lower margin are not compensated by forward movement of the ice to the same degree as in the more mobile primary glaciers.

Glaciers of Mount Hood

The Research Committee of the Mazamas, of Portland, Oregon, last year, as usual, remeasured the more important glaciers on Mount Hood, and in addition extended its studies to some of the lesser ice-streams, principally to obtain comparisons with photographs taken in earlier years.

Eliot Glacier, the longest glacier on the peak, situated on the northeast side, was found to have receded 20 feet from September 20, 1936, to September 11, 1937. During a comparable period a year ago it receded 21 feet.

Comparison of a photograph of the terminus taken on September 11, 1937, with one published in 1912, in J. H. Williams' book, "The guardians of the Columbia," shows that during the past 25 years the glacier has receded several hundred feet and has lost, by estimation, fully 100 feet in thickness. Cryocinemeter-measurements at the terminus indicated a forward movement of the ice averaging 0.66 inch in 24 hours.

Coe Glacier, on the north side of the peak, had receded 29 feet during the 23-month period from October 20, 1935, to September 11, 1937. Cryocinemeter-measurements at the terminus indicated a forward movement of the ice averaging 1.09 inches in 24 hours. The rate of movement actually varies widely during different parts of the day, presumably in response to changes in temperature.

Newton Clark Glacier, on the east side of the peak, was rephotographed by A. J. Gilardi on September 12, 1937, from the identical point from which Dr. Harry Fielding Reid photographed it on July 25, 1901. Comparison of the photographs reveals an amazing reduction in both extent and thickness. The recession, which is difficult to estimate because of the irregular shape of the ice-body, amounts to about 500 feet, and the decrease in thickness averages fully 100 feet.

Palmer Glacier, situated on the south slope of Mount Hood, just west of the canyon of the White River Glacier, is the remnant of an ice-tongue that was formerly fed by overflow from that glacier. A recent experiment shows that it is now reduced to a stagnant ice-field. On October 11, 1936, a wire was stretched across one of the lower tongues of the ice-body, 75 feet in breadth. A trench was cut along the wire, filled with orange pigment and again filled with snow. On October 9, 1937, the line was reexamined and found still identifiable by means of the pigment. It showed no movement although the surface had been lowered several feet by ablation.

Langille Glacier is the name proposed for the ice-body that lies just west of Langille Crags, on the north slope of the peak. When mapped in 1907 it was a compact mass extending from an altitude of 7,500 feet down to an altitude of 6,500 feet. It is now greatly reduced in area and has become severed into two thin lobes each of which ends in a lakelet held by a terminal moraine.

Observations on these relatively insignificant ice-bodies may at first seem to have little value; nevertheless, it is hoped that they will be repeated from time to time, for these small residual ice-masses are on the verge of extinction, and unless there is a change in the trend of climatic conditions that will insure their early rehabilitation they will probably vanish entirely within the next ten or twenty years.

Aerial photographic surveys of the glaciers of the Cascade Mountains

On September 25, 1935, Kenneth N. Phillips, Chairman of the Research Committee of the Mazamas, accompanied by Adrian J. Gilardi, member of that Committee, and L. J. Baily, photographer, encircled Mount Hood in an airplane and secured a set of excellent oblique photographs of its entire glacier system.

So valuable did these aerial photographs turn out to be as a means of recording the extent, form, and characteristics of each glacier, and such accessory features as moraines, proglacial lakelets, the course of effluent streams, and the height of the timber-line near by, that it was decided to make a more extended flight the following year around some of the other glacier-bearing peaks of the Cascade Mountains. Accordingly, on October 6, 1936, a flight was made encircling Mount Adams, Mount Rainier, and Mount St. Helens, in the State of Washington. A set of photographs was taken, portraying the numerous glaciers on each of these three peaks, and again much valuable information was secured that could not possibly have been obtained by ground observations.

On September 24, 1937, a third flight was made embracing the glacier-bearing peaks of

north-central Oregon--Mount Jefferson, Three-fingered Jack, Mount Washington, and the Three Sisters--and as a result there is now at hand, for the first time, a collection of aerial photographs depicting all of their relatively little-known glaciers.

These photographs have been mounted in two annotated albums that constitute, in effect, geographic reports in pictorial form. The first of these albums contains the views of Mount Adams, Mount Rainier, and Mount St. Helens; the second contains the views of Mount Hood, Mount Jefferson, Three-fingered Jack, Mount Washington, and the Three Sisters.

A copy of each of these albums has been generously presented by the Mazamas to the Committee on Glaciers. The Committee takes this opportunity publicly to express its high appreciation, and to congratulate the Research Committee of the Mazamas on the success of its aerial reconnaissances. Whatever time, effort, and expense have gone into them have been well spent, for these collections of aerial photographs will form a much-needed groundwork for future glaciologic research. It is to be hoped that similar collections will be made in the course of time, covering all of the more important glaciers of the western United States.

Glaciers of the Sierra Nevada

C. A. Harwell, Park Naturalist of Yosemite National Park, California, and his assistants last autumn revisited the five glaciers on the crest of the range to which measurements are annually made. Three of these--the East Lyell, West Lyell, and Maclure--are within the Park, the other two--the Dana and Conness--are just outside its eastern border. The results were as follows:

East Lyell Glacier on September 24, 1937, was found to have receded only six feet from its position in 1936.

West Lyell Glacier had receded 14 feet and had lost at least six feet in thickness at its lower end. Mr. Harwell's handsomely illustrated report contains an unusually instructive photograph showing clearly the system of concentrically outcropping ice-layers in the surface of this glacier, which was completely divested of recent snow, save at its extreme head. Superimposed unconformably on the broad main mass lies a long, narrow ice-tongue composed of a more recent series of layers. On the upper half of the glacier, again, the central tongue disappears beneath another, shorter tongue composed of a third unconformable and still more recent series of layers.

It is here suggested that each of the two superimposed series represents an accumulation made during a relatively recent period, or cycle, of glacier-growth, and that each of the two marked unconformities indicates strong ablation during a prolonged period, or cycle, of glacier-wastage. The youngest series of beds is perhaps to be correlated with the cycle of wet years that is definitely recorded in the varying levels of Mono Lake, at the eastern base of the Sierra Nevada, and that culminated during the years 1919 to 1922 [see S. T. Harding, Changes in lake levels in Great Basin Area, Civ. Eng., v. 5, No. 2, February, 1935, pp. 89-90].

Maclure Glacier, like West Lyell Glacier, was found stripped of its snow-cover except in the vicinity of the bergschrund. It had receded 13 feet since the autumn of 1936.

Dana Glacier, by contrast, was still partly covered with snow. Large masses of snow blanketed its lower margin, and as a consequence recession-measurements could be made only from two of the four stations that are regularly used. At station 3-A the ice had receded 10 feet, and at station 5-A it had receded 33 feet.

Conness Glacier, again, was largely stripped of its snow-cover, and appeared to have sustained greater losses from ablation during the past year than any of the other glaciers of the central Sierra Nevada. Its eastern lobe had receded no less than 90 feet and had become reduced to a relatively thin sheet.

Glaciers of Glacier National Park, Montana

Dr. George C. Ruhle, Park Naturalist of Glacier National Park, reports the following figures for the recession of three of the more accessible glaciers:

Siksikaikwan Glacier (formerly west lobe of Blackfoot Glacier) on September 20, 1937, had receded 28 feet from the position it occupied in September, 1936. Its total recession for the last two years is 132 feet, but the total for the last five years is only 70 feet, there having been advances in 1933 and 1935.

Sperry Glacier had receded 29 feet during the year ending September 17, 1937. It is gradually breaking up into several small ice-bodies and now falls far short of covering the broad shelf which it mantled almost completely in 1901, when the topographic map of the Chief Mountain Quadrangle was made by the United States Geological Survey.

Grinnell Glacier, visited on October 25, 1937, was found to have held its own during the past 12 months, having receded only four feet.

During the summer of 1937 a detailed topographic map was made of the Grinnell Glacier and its surrounding moraines on a scale of 1:2,400, and with 20-foot contour-intervals. This work marks the beginning of a mapping program which, it is hoped, will ultimately be extended to all of the larger glaciers of the Park, and will afford a splendid groundwork for future glaciologic studies.

Glaciers of Rocky Mountain National Park, Colorado

To H. R. Gregg, Park Naturalist of Rocky Mountain National Park, we are indebted for resumption, in 1937, of recession-measurements to the Andrews and Tyndall glaciers. Measurement of these glaciers was begun in 1932 but had lapsed in 1936 owing to changes in the personnel of the Park.

Both glaciers are small, measuring only half a mile or less in length, but they are representative of the type that prevails in the central portion of the Rocky Mountains, and annual observations on them are, therefore, of special importance.

Andrews Glacier on October 13, 1937, was found to have melted back 31 feet since it was visited in 1935. Its complete record is as follows: 1932-1933, -10 feet; 1933-1934, -80 feet; 1934-1935, +73 feet; 1935-1937, -31 feet; net change since 1932, -48 feet.

Mr. Gregg's report is illustrated with photographs showing successive stages in the recession of the small cirque glacier from September 1928, when it fronted broadly on the lakelet at its foot, to September 28, 1937, when it was separated from the lakelet by a delta 35 feet long.

Tyndall Glacier appeared to have receded no less than 163 feet in the two-year interval since 1935. Its complete record is as follows: 1932-1933, -33 feet; 1933-1934, -9 feet; 1934-1935, +34 feet; 1935-1937, -163 feet; net change since 1932, -171 feet.

Particularly impressive is the evidence of great reduction in thickness and in volume of the Tyndall Glacier from September, 1928, to the present time, that is afforded by the photographs included in the report.

Glaciers of Alaska

From Harry J. Liek, Superintendent of Mount McKinley National Park, word was received that he has at last succeeded in making initial measurements to the fronts of three ice streams in the Park--the East Fork Glacier, the Toklat Glacier, and the Sunset Glacier.

Bayne Beauchamp of Honolulu, Territory of Hawaii, who visited Valdez, Alaska, and several of the glaciers in its vicinity in 1936, has kindly transmitted to the Committee copies of two old records of the recession of Valdez Glacier that are in the possession of the Order of Moose at Valdez. One of these goes back to 1898, when the great "gold rush" to this part of Alaska took place. Though these two records do not agree throughout, they indicate the same total recession of 918 feet. Both are given here as transmitted:

Paced distances from a stone monument on a mound near the front of the glacier (location of monument not positively identified by Beauchamp)

Date	Steps	Feet	Recession in feet
1898-99	?	±150	
1901	70	210	60
1902	83	249	39
1904	138	414	165
1905	171	513	99
1908	70 steps + 583 feet	796	283
1909	?	840	44
1914	?	918	78

Dates	Recession in feet	Total recession since 1901
June 6, 1901 - June 18, 1902	39	39
June 18, 1902 - June 7, 1904	165	204
June 7, 1904 - June 16, 1905	99	303
June 16, 1905 - Oct. 13, 1908	283	586
Oct. 13, 1908 - June 21, 1909	44	630
June 21, 1909 - Aug. 10, 1914	288	918

Mean annual recession for the 13-year period is 70.6 feet. The second set of measurements is presumably the more reliable of the two. It was made by Dr. L. S. Camicia and Joseph A. Bourke (both deceased). Transmitted with these records is a sketch map of the front of Valdez Glacier, showing distances measured to its front by Beauchamp's party, and location of reference-points.

In addition, there were received from Beauchamp notes on three glaciers situated near the Richardson Highway leading from Valdez to Fairbanks. These are the Worthington Glacier, situated 29 miles from Valdez; the Cache Creek Glacier, situated 50 miles north of Valdez; and the Gakona Glacier, situated about midway between Valdez and Fairbanks. Accompanying the notes are photographs of the glaciers and sketch maps showing the location of rock-cairns built for future reference-points.

Black Rapids Glacier, whose phenomenal advance threatening the Richardson Highway, during the winter of 1936-37, gave it front-page notoriety as the "runaway glacier," has now lapsed back to the sluggish, almost imperceptible movement characteristic of most glaciers.

The most complete report on its phenomenal advance, and the probable causes thereof, has been presented by Professor James H. Hance of the University of Alaska in a paper entitled "The recent advance of Black Rapids Glacier, Alaska" (J. Geol., v. 45, No. 7, Oct.-Nov. 1937, pp. 775-783). A brief note by Fred. H. Moffit of the United States Geological Survey entitled "Runaway glacier caused by friction and skidding" was published in Science News Letter for January 15, 1938.

The advance was estimated at about three miles. The precise date of its beginning is unknown, but if it is assumed that it began late in September or early in October, 1936, the average forward movement of the ice-front per 24 hours would probably have been 115 feet. Between February and June, 1937, advances as rapid as 250 feet per day were reported by local observers, but Professor Hance believes that "crumbling and flattening of the steep front may account for some of these phenomenal figures."

Professor Hance is inclined to attribute the rapid advance primarily to excessive snow-precipitation in the mountains surrounding the broad gathering basin at the head of the glacier, during 1929 to 1932, which was followed by another period of somewhat more than normal precipitation during 1929 to 1936. (The only precipitation-data available are those from the Weather Bureau station at Fairbanks, about 140 miles to the northeast; these are probably not representative of the conditions that obtained in the mountain area.) The rapidity of the forward movement is attributed to the narrowness of the outflow canyon, as compared with the breadth of the basin drained. Terminal moraines situated west of the Delta River show that the glacier has made somewhat similar advances in fairly recent times.

Moffit does not regard excessive snowfall as the primary cause of the rapid advance of the Black Rapids Glacier. If excessive snowfall had been the cause, he argues, then every glacier in the same mountain area would have "run away." The fact that the Black Rapids Glacier was the only one that behaved so extraordinarily, he insists, points to a local cause. That cause is very probably to be found in the extreme narrowness of the outflow canyon as compared with the breadth of the capacious gathering basin above. The great frictional resistance of the canyon-walls must have caused the ice to accumulate in the basin for many years until at last there was sufficient pressure or "head" to force outflow. Probably the resistance was overcome rather suddenly, and the outflow therefore took place with unusual velocity.

It may be presumed that similar sudden and rapid forward surges have occurred periodically throughout the life of the glacier, and this presumption seems to be borne out by two concentric moraines situated about one mile and one-half mile from the present front of the glacier.

U. S. Geological Survey,
Washington, D. C.

Compliments of François E. Matthes

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REPORT OF COMMITTEE ON GLACIERS, 1940-41

François E. Matthes, Chairman

(Published with the approval of the Director of the Geological Survey)

The personnel of the Committee is now as follows: Harry Fielding Reid, Professor Emeritus of Geology, Johns Hopkins University, 608 Cathedral Street, Baltimore, Maryland; William H. Hobbs, Professor Emeritus of Geology, University of Michigan, Ann Arbor, Michigan; Lawrence Martin, Chief of the Division of Maps, Library of Congress, Washington, D. C.; J. E. Church, Professor of Meteorology, Agricultural Experiment Station, University of Nevada, Reno, Nevada; Wm. Osgood Field, Jr., Explorer, 18 West Twelfth Street, New York, New York; Oliver Kehrlein, Chairman, Committee on Glacier Studies of Sierra Club, 1050 Mills Tower, 220 Bush Street, San Francisco, California; Kenneth N. Phillips, Associate Hydraulic Engineer, Water Resources Branch, United States Geological Survey, Chairman, Research Committee of the Mazamas, 606 Post-Office Building, Portland, Oregon; William S. Cooper, Professor of Botany, University of Minnesota, Minneapolis, Minnesota; Gerald Fitzgerald, Senior Topographic Engineer, Alaska Branch, United States Geological Survey, Washington, D. C.; Laurence M. Gould, Professor of Geology, Carleton College, Northfield, Minnesota; Dr. Max Demorest, Department of Geology, Yale University, New Haven, Connecticut; François E. Matthes (Chairman), Senior Geologist, Section of Glacial Geology, United States Geological Survey, Washington, D. C.

Dr. Otto Lütschg, President of the International Association of Scientific Hydrology, acting for its Executive Committee, has appointed Dr. Church President of the International Commission of Snow and Glaciers, and Mr. Matthes Secretary of that Commission, for the period 1939-42.

The following records of recession and shrinkage in volume of American glaciers were received from the field during the past year:

Glaciers of Mount Rainier, Washington

A report by FRED F. LAWRENCE, of the Conservation Branch of the United States Geological Survey, on the third resurvey of the lower Nisqually Glacier in 1940, shows that the terminus of that Glacier has receded 70 feet from the position it occupied in 1939 and 300 feet since the previous survey was made in 1936. The average annual recession during the past 22 years has been 72 feet, hence it appears that the general rate is being maintained essentially unchanged.

Recession-figures during the 22-year period have shown considerable departures from the mean, falling as low as 43 and 44 feet in some years and rising as high as 118 and even 155 feet in other years. A plot of the recession-figures made by the present writer, however, indicates no evidence of any cycles, and it can only be inferred that the departures from the mean are due to the various climatic factors that annually affect the economy of a glacier such as the Nisqually, which has a length of 4-1/2 miles and makes a descent of over 10,000 feet in altitude from the summit névés on the peak.

The original plan of repetitive surveys of the Nisqually Glacier, by the Geological Survey, in cooperation with the City of Tacoma Light Department (which depends for power upon the Nisqually River), called for remapping at intervals of five years. The first survey was made in 1931, the second in 1936, and the third was scheduled for 1941. However, so rapid has been the shrinkage of the Glacier during the last few years that it was decided to make the third survey in 1940.

In 1931 and 1936 the mapping was done on a scale of 1:4,800 with a contour-interval of 20 feet. It was soon found, however, that a smaller scale and larger contour-interval would afford sufficiently accurate data for the computations of loss of volume of the Glacier, and accordingly the 1940-survey was made on a scale of 1:96,000 and with a contour-interval of 50 feet. The stretch mapped in each case comprised the lower 10,000 feet of the ice-stream--that is, somewhat less than the lower half.

The longitudinal profiles based upon the successive surveys show that the Glacier's surface over a stretch of 3,000 feet was lowered by ablation from 30 to 60 feet during the five-year period 1931-36, and on an average somewhat more during the four-year period 1936-40. At the terminus, of course, the losses were still greater, averaging about 70 feet during each period. Since 1910, when the Glacier was mapped on a scale of 1:48,000 and with a contour-interval of 100 feet, in connection with the survey of the entire Mount Rainier National Park, the vertical losses over the 3,000-foot stretch before mentioned have averaged about 200 feet or about 6.6

feet per year. In the middle of the stretch the loss has been not less than 240 feet, or eight feet per year. It will be noted that during the period 1931-36, ablation proceeded at the rate of 6 to 12 feet per year; and during the period 1936-40 it reached a maximum of 15 feet per year.

Of peculiar interest is the fact that above the altitude of 5,600 feet the losses have been very variable. During the period 1931-36 the Glacier there actually increased in thickness from 10 to 40 feet, only to be reduced again 50 to 60 feet during the period 1936-40.

Without going into an account of the method adopted for the computation of losses in volume, it may be stated that the curves in Mr. Lawrence's report show that during the period 1910-31 the losses of ice in the surveyed portion of the Nisqually Glacier aggregated about 500 acre-feet per year; during the period 1931-36 they aggregated about 750 acre-feet per year; and during the period 1936-40 they aggregated not less than 3,400 acre-feet per year. These figures afford impressive testimony of the rapidly increasing reduction of the Nisqually's volume, which is not apparent from the constant rate of recession of its terminus.

Measurements by C. FRANK BROCKMAN, Park Naturalist of Mount Rainier National Park, on the Emmons Glacier, the largest ice-stream on Mount Rainier, show that it has receded 97 feet since the preceding year. This is considerably more than the average for the past decade. It is to be noted, however, that recession-measurements in the case of a glacier such as the Emmons, which ends in vast masses of stagnant, or partly stagnant ice thickly mantled by morainal débris, can hardly furnish more than approximate values. They serve nevertheless to indicate the general order of magnitude of the Glacier's recession from year to year, and it is to be hoped, therefore, that such measurements will continue to be made in the future.

The Carbon Glacier during the past year receded nearly twice as fast as at any time since measurements were begun. This ice-stream originates in a large cirque carved in the north flank of the peak, at an altitude of only 9,600 feet--that is, at a level nearly 5,000 feet below the summit. It is, however, fed in considerable measure by avalanches from the ice-cap on the summit platform. The lower end of the Glacier lies ensconced in a narrow, steep-walled gorge, and that circumstance probably accounts for the slowness of its recession as compared with the Nisqually and Emmons glaciers.

Year	Recession in feet	Year	Recession in feet
1936-37	20	1938-39	25
1937-38	18	1939-40	46

The South Tahoma Glacier, situated on the south-southwest side of Mount Rainier, also originates in a cirque but differs from the Carbon Glacier in that it receives no reinforcements by avalanching from the summit platform. It also showed a marked increase in the rate of its recession during the past year. Like the Emmons Glacier it is heavily encumbered at its lower end by morainal material released by ablation and therefore also presents difficulties for the determination of its recession. Three different reference points have been used by Mr. Brockman for his measurements. Here only the measurements from point B are recorded.

Year	Recession in feet	Year	Recession in feet
1936-37	13	1938-39	67
1937-38	76	1939-40	91

The Paradise Glacier is of peculiar interest because it does not originate high up on the flanks of Mount Rainier but occupies a gently sloping shelf at altitudes ranging from 6,300 to 7,200 feet. It is fed in large part by direct precipitation and wind drifting but doubtless receives considerable reinforcements also from the steeply sloping névé fields to the south of Anvil Rock. It is only 1-1/4 miles long and is often referred to as a "dead glacier." That appellation, however, is hardly justifiable, in view of the fact that there is, or has been until last year, enough movement in the mass to sustain three marginal lobes. The central one of these, commonly known as the Stevens Glacier, because it drains into Stevens Canyon, is now in truth dying, as it has become detached from the main mass. All that remains, according to Mr. Brockman, is a thin slab of ice about one-quarter mile long and separated from the main Glacier by 200 yards of bare rock.

The southern lobe of the Paradise Glacier, best known to the public because most readily accessible, receded but slowly during the past year, less, in fact, than during previous years. That fact is probably accounted for by the progressive thinning of the Glacier by ablation. No record of the reduction of its surface has been kept, but there is every reason to believe that

the reduction is going on apace, in view of the southerly exposure of the Glacier, the absence of shadow-casting cliffs on either side, and the absence also of a protecting debris-cover. Following is the record of recession of the southern lobe.

Year	Recession in feet
1936-38 (2 years)	83
1938-39	75
1939-40	30

Significant in connection with the foregoing records of glacier-recession are the meteorologic data which Mr. Brockman appends to his report: The snow-precipitation during the winter of 1939-40, as recorded in Paradise Valley, at an altitude of 5,557 feet, amounted to only 402 inches as compared with a normal fall of 625 inches. Mean temperatures during the past year were about 18 per cent above the average.

Glaciers of Mount Hood, Oregon

The Research Committee of the Mazamas, of Portland, Oregon, according to the report of KENNETH N. PHILLIPS, Chairman, on September 21, 1940, revisited the Eliot Glacier, the largest ice-stream on Mount Hood, and by tape-measurement determined its recession since September 24, 1939, to be 18 feet. In view of the fact that temperatures during the period July, 1939, to September, 1940, had been decidedly above normal for each month, and that the snowfall on Mount Hood had been very slight during October and November, and until December 8, 1939, it was expected that the recession of the Eliot Glacier would be much more than 18 feet, "perhaps even more than the 64-foot retreat observed in 1938-39". The relatively slight change in the length of the Glacier, therefore, seemed difficult to account for with the data at hand. "However," suggests Mr. Phillips, "it seems possible that the forward movement of the Glacier during the year was considerably greater than normal owing to the warm weather, thus compensating largely for the greater ablation by melting and evaporation."

The party, further, took the first steps toward determining the rate at which the Glacier's surface is being lowered by ablation from year to year, by running two transit-stadia profiles across it and marking the end points thereof on the lateral moraines. The lower line is situated about 300 feet above the beginning of the terminal face of the Glacier, the upper line about one-quarter mile farther upstream. The two profiles will be resurveyed at intervals of two or three years to determine the vertical losses by ablation.

Cryocinemeter measurements were made on September 21-22, 1940, to determine the rate of advance of the terminus in autumn weather. Over a period of 23 hours, 45 minutes, the total advance observed was 0.482 inch, a rate of 0.487 inch per day. The temperature during the period of observation ranged from about 40° to 60° F.

The Research Committee also continued its recently inaugurated program of recording temperatures on the summit of Mount Hood with maximum and minimum thermometers. The minimum recorded for the winter of 1939-40 was -6° F (probably higher than the true minimum, as the thermometer-box had become covered with several feet of snow). The maximum, recorded on August 20, 1940, was 69° F.

The remnants of an ancient forest of large trees that once grew on the flanks of Mount Hood at altitudes as high as 7,500 feet--that is, considerably above the present timber-line for large trees--were briefly examined by Professor DONALD B. LAWRENCE, of the University of Minnesota, and Mr. Phillips. These remnants are situated in the valley of White River, which is cut in the south flank of the peak, and they probably are the same which A. H. Sylvester of the United States Geological Survey discovered in 1906, when he was making the topographic map of Mount Hood and its vicinity. The interest that attaches to them is that they may indicate a relatively recent period of mild, rainy climate during which the timber-line lay at a much higher level than at present.

As was mentioned in the first annual report of the Committee on Glaciers [Trans. Amer. Geophys. Union, Thirteenth Annual Meeting, pp. 282-287, 1932; this reference on p. 286] remnants of another ancient forest--the Stadter Buried Forest--were found in 1926 by a party of Mazamas, while on a climb near the timber-line on the southwest slope of Mount Hood. These remnants consist of long, straight trunks lying in a tangled mass beneath what is believed to be a recent moraine of the Zigzag Glacier, and they are being exposed to view by the incision of a new stream-cut gully.

The rings of growth in those ancient trees average about 18 to 20 to the inch--that is, they are about the size of the rings in trees such as grow today about the base of Mount Hood. The rings in timber-line trees, by contrast, average more nearly 100 to the inch. There is good reason to believe, therefore, that the ancient forest grew high up on the slopes of Mount Hood at a time when, because of milder climate, the timber-line lay at least a thousand feet higher than it does at present. Now that the occurrence of a period of warmer climate than the present during the middle third of the Post-Pleistocene interval is definitely established by several independent lines of evidence, in Europe as well as in North America and in New Zealand, these ancient "buried forests" at high levels on Mount Hood gain new significance, and it seems well worth while to investigate them with care, in order to determine, if possible, whether they date back to the "climatic optimum" of the Post-Pleistocene interval.

Glaciers of the Sierra Nevada, California

The report by M. E. BEATTY, Acting Park Naturalist of Yosemite National Park, gives the results of measurements both of recession and of reduction of surface for several glaciers.

The toe of the East Lyell Glacier on October 4, 1940, was still covered with snow, hence no recession-measurement could be made. Reduction of the surface of the Glacier by ablation, on the other hand, was determined at two points on a profile across the middle of the Glacier that had been established in 1933. At Station 1, 504 feet from the west end of the base-line, there was a vertical loss of 4.4 feet since 1939, and at Station 2, 768 feet out, the vertical loss was 6.8 feet. At Station 1, the total loss in seven years amounted to 22.3 feet; at Station 2 it amounted to 38.8 feet. The mean annual loss for the seven-year period, therefore, was 3.2 feet at Station 1, and 5.6 feet at Station 2. Assuming that the Glacier has a maximum thickness in its cirque of about 300 feet, it will, at the present rate of melting, cease to exist in about 50 years.

A measurement to the front of the West Lyell Glacier showed a recession since the previous year of three feet. What is more significant, however, is that measurements with an Abney level to two points on a profile across the Glacier established in 1933 showed a lowering of the surface by ablation closely similar to that on the East Lyell Glacier. At Station 1, 311 feet distant from the west margin, the vertical loss since 1939 proved to be 2.8 feet; at Station 2, 714 feet distant, the vertical loss was 6.3 feet. During the seven-year period since 1933 the surface of the Glacier was lowered 17.2 feet at Station 1, and 26.4 feet at Station 2. The mean annual vertical loss for the seven-year period, therefore, was 2.5 feet at Station 1, and 3.8 feet at Station 2.

The Maclure Glacier in 1940 showed but little change in appearance since 1939. No measurement of recession was possible, owing to the large "cave-in" that had taken place at its front in what supposedly was morainal material, but what proved to be moraine-covered glacier-ice. The cave-in was due, of course, to the melting out of a cavern in the ice by a stream issuing from the base of the Glacier.

Measurements to the broad front of the Dana Glacier could be made only at two points. At Station 3 the ice had receded 30 feet since 1939; at Station 6 there had been a recession of not less than 64 feet.

Glaciers of Glacier National Park, Montana

JAMES L. DYSON, during the summer of 1940, visited six of the larger glaciers of Glacier National Park and found them all in a state of accelerated recession. The winter of 1939-40, he reports, was one of the most open winters on record in that part of the Rocky Mountains. The snowfall was so light that the roads into some of the higher areas were passable throughout the greater part of the winter. That fact, coupled with a prolonged period of high temperatures during the ensuing summer, resulted in an unusually great diminution of the glaciers in the Park. From some glaciers all of the snow that fell during the winter of 1939-40 was completely removed, and from most of the smaller ice-bodies the compacted névé of several preceding winters was removed also.

Measurements to the front of the Grinnell Glacier showed that the recession during the summer of 1940 alone (up to September 6, 1940) amounted to more than 39 feet, whereas the previous recession since August, 1937, had been only 26 feet. Mr. Dyson's measurements are as follows.

Dates	Interval	Recession
August 29, 1937 to July 27, 1939	1 year, 11 months	20 feet
July 27, 1939 to July 3, 1940	11 months	6 feet
July 3, 1940 to August 11, 1940	1 month	18 feet
August 11, 1940 to September 6, 1940	1 month	21 feet
Total in 3 years		65 feet

The detailed map of the Sperry Glacier, which Mr. Dyson made for the National Park Service in 1939, showed a projecting ice-mass 700 feet long and from 200 to 600 feet in width, on the west side of the main body of the Glacier. All of this projection had disappeared late in August, 1940.

The Chaney Glacier appeared to have been reduced 8 to 10 feet in thickness.

The Shepard Glacier, which around the beginning of the present century rested on two rock shelves separated by a vertical cliff that was exposed only at the northern end of the ice-mass, in 1940 was confined largely to the upper shelf, and had been reduced to less than one-half its former surface area.

The Agassiz Glacier, which in 1900 covered an area of about 1.40 square miles and was one of the two largest and most spectacular glaciers in the Park, in 1940 had been reduced to two disconnected masses of stagnant ice aggregating together no more than 0.29 square mile. Whereas in 1900, to judge by the position of the fresh terminal moraine, it probably had a thickness of several hundred feet, the two remaining masses appear to be not over 35 feet thick. It is clear that, if the present climatic trend continues, the Agassiz Glacier--named for the father of glaciology--will cease to exist in only a very few years.

The glacieret at Iceberg Lake, which as late as 1920 still extended a considerable distance out into the Lake and had a frontal cliff 90 to 100 feet high, from which icebergs calved off from time to time, in 1940 had melted back from the border of the Lake and ceased to produce the icebergs which heretofore were an object of interest to the visiting public.

Mr. Dyson also had opportunity to visit the Grant Glacier on the Flathead Range, to the south of Glacier National Park. It appeared wholly divested of snow in the summer of 1940, and, to judge from its relation to the fresh moraine, which it probably touched in 1900, it is now only about one-half as large as it then was.

Glaciers of the Wind River Range, Wyoming

To FLOYD WILSON, of Burris, Wyoming, the Committee is indebted for information on the recession of the principal glaciers of the Dinwoodie Group, near Gannett Peak. All of these glaciers are in recession and evidently have been for a number of years. Markers were set only below the Gannett Glacier and its branches, and as a consequence figures of recession can be given for these only. The main Gannett Glacier, according to Mr. Wilson's measurements, receded not less than 102 feet during the summer of 1940. The middle fork of the Glacier receded 87 feet. The south fork, he estimates, must have receded about 500 feet in the last five years.

Glaciers of Rocky Mountain National Park, Colorado

H. R. GREGG, Park Naturalist of Rocky Mountain National Park, has continued to make measurements of the recession of the Andrews and Tyndall glaciers. These belong, both of them, in the "vestigial" class and for that reason are of unusual interest. Both are steeply sloping masses of leminated ice situated in relatively small cirques on the east side of the Continental Divide. The recession of these glacierets amounts to only a few feet per year and in some years is not measurable because of accumulations of snow on the terminus. Apparently, because of their sheltered positions, both of these glacierets suffer less, proportionately, from the increasing dryness and warmth of the climate, than the much larger glaciers in Glacier National Park and in the Pacific Northwest.

Glaciers of Mount McKinley National Park, Alaska

FRANK T. BEEN, Superintendent of Mount McKinley National Park, reports that he has at last succeeded in obtaining a measure of the recession of the Sunset Glacier. It had receded 12 feet since the summer of 1939.

Difficulty has been experienced during past years in measuring the recession of the East Fork and Toklat glaciers, partly owing to inclement weather, partly because the monuments built for reference-points are frequently washed away by floods. It is reasonably certain, however, that all of these glaciers on the Alaska Range are in a state of recession.

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