THE UNDESCRIBED GLACIERS OF MOUNT RAINIER (*1)

F. E. Matthes

In the Rainier number of this magazine, which appeared in 1909, Alida J. Bigelow gave an able synopsis of the late Prof. Israel C. Russell's report to the U. S. Geological Survey on the glaciers of Mount Rainier (*2). As she pointed out, that report does not cover the entire series of glaciers of the great volcano, the Kautz, Wilson, Tahoma, Puyallup, and Edmunds Glaciers not being described in it. The fact is that Prof. Russell in the short time at his command, was unable to completely encircle the mountain. Its west and southwest flanks as a consequence remained unknown to him.

The topographic surveys which the U. S. Geological Survey has lately been carrying on in the Mount Rainier National Park fortunately embrace the very portion of the mountain which Russell did not see, and thus there is now at hand a considerable body of data on the glaciers that have hitherto remained undescribed.

The brief descriptions that here follow hardly dare aspire to complement Russell's classic studies; they are offered merely in a preliminary way, in the hope that some day they may be superseded by more thoroughgoing and detailed discussions. In the meanwhile, however, they may prove of interest not simply because they fill a gap long vacant, but because they also seem to indicate the need of a revision of our general conception of the glacier system of Mount Rainier.

That system, which was first outlined by Russell, comprises glaciers of two classes: primary and secondary; the primary glaciers being those having their sources on the summit of the mountain, the secondary glaciers (also termed interglaciers) being those originating well down on its flanks, as a rule in the hollows of the triangular tracts that separate the

(*1) Published with permission of the Director of the U. S. Geological Survey.

(*2) The Glaciers of Mount Rainier, 18th Ann. Rept., U. S. Geological Survey, Part II, pp. 349-415.

Plate XIII.

VIEW TAKEN FROM SOURDOUGH MOUNTAIN
Chas S. Gleason

Taken from elevation 7500. looking south by east and showing: From left to right, on the sky-line. Frying Pan glacier, Little Tahoma, north side of Gibraltar rock, Crater peak, Russell peak, and Liberty cap; in the middle distance, White glacier, Ruth mountain, Camp Curtis, Steamboat prow, Interglacier, Elizabeth pass, Winthrop glacier, and east side of Willis Wall. In the middle foreground is Glacier basin, the site of Mountaineer's Camp No. 8, July 30 to August 3, 1912.

diverging primary glaciers. While this classification admirably fits the conditions on the east half of Mount Rainier, it is scarcely applicable to the west half. Indeed all the large glaciers on the west half, with the exception of one, originate in amphitheatres or "cirques" situated some 4,000 feet below the summit. In point of magnitude, however, they are quite on a par with the summit born glaciers, and to call them "secondary" or "interglaciers" would seem scarcely appropriate. A careful analysis, moreover, shows that the great Carbon Glacier itself—the second largest ice stream on Mount Rainier—is really a cirque-born glacier of the same type as the other cirque glaciers on the west flank. Surely no one would think of placing the Carbon Glacier in the secondary or interglacier class.

In the following, therefore, the distinction between primary and secondary glaciers, as drawn by Russell will be dropped. At the same time, the term "interglacier" will be retained as most apt for the designation of those intermediate ice bodies of small extent that are situated on the "wedges" between the larger glaciers.

Van Trump Glacier. Beginning immediately west of the Nisqually Glacier, the last ice stream on the southeast side of the mountain described by Russell, we find a huge "wedge" that tapers upward in a sharp point. That point, which has an altitude of 13,000 feet, is a remnant of the great crater rim produced by the explosion that removed the original top of the volcano. Immediately below the point is a small hollow in which névé has accumulated for ages. The effect has been to enlarge the hollow until the ridges separating it from the great glaciers to the right and left are now reduced to slender "arrêtes" or "cleavers" as they are locally quite aptly called.

The process illustrated by this tiny interglacier has been repeated in a number of places on the great wedge. Every hollow in its irregular surface has been occupied by a small névé mass, and through the peripheral sapping action that invariably takes place around such ice bodies, these hollows have been enlarged, until now they are separated from each other only by narrow rock walls or cleavers. Thus the wedge has the appearance of carrying a number of ice-filled compartments with intermediate rock partitions. In some instances, even, these partitions have been partly destroyed and the compartments communicate, so that their ice masses coalesce. The most conspicuous case is found in the central area where a number of basins, large and small, have united, so that their snows now flow together. This compound névé field is known as the Van Trump Glacier.

In former times, especially at the height of the glacial epochs, the Van Trump Glacier must have been much thicker and far more extensive than now, and many of the small ice tongues which, owing to the rapid shrinkage of the last decades are now threatening to become detached, were then part and parcel of the whole. At its lower border the Van Trump Glacier sent forth six lobes, each lying in a deep and narrow groove. These were confluent and ultimately formed two good-sized glaciers and a minor one that traversed the valleys of that charming park country for which the name Van Trump Park has recently been suggested.

Kautz Glacicr. Immediately west of the great wedge that bears the Van Trump Glacier lies the ice stream named for Gen. A. V. Kautz, the first explorer to attempt the scaling of the peak. It has its sources in the summit névés south of the new crater. It is a singularly narrow glacier, averaging only one-half to one-fourth the width of the Nisqually, or about 1,000 feet. At the same time it is fully as long as the Nisqually, that is, exactly four miles, according to the new topographic surveys. It receives but one tributary of any size, a glacier still nameless that originates in a profound cirque under Peak Success. At first sight the volume of that glacier appears to be equal to that of the main stream, but the medial moraine which begins at their confluence, by its gradual shifting farther and farther west from the central axis of the glacier, shows that the tributary ice stream is the lesser of the two.

The medial moraine, which is almost two miles long, is very similar to that of the Nisqually Glacier, and like that moraine gradually gains in width and height toward the lower end of the ice stream so that at last it stands out above the ice like a strong embankment. The lower third of the glacier lies encased in a narrow canyon, the depth of which steadily increases downward, until at the glacier end it amounts to nearly a thousand feet. Below the glacier end the canyon suffers a remarkable constriction. For a distance of a quarter of a mile it has a width of only 400 feet. The walls are nearly vertical, composed of columnar basalt, and it would seem as if the glacier during the times of its greater extension has had to squeeze through this narrow strait, unable to effect any considerable lateral erosion in this resistant material. Closer study, however, reveals the fact that the buttress on the west side of the gorge has formerly been overridden by the ice. The glacier, therefore, when at its greatest height, did not content itself with the avenue afforded by the narrow passage, but overrode the obstruction of hard lava to the west, thus securing an outlet one-quarter to one-half a mile in width.

Immediately below the constriction, curiously, begins the broad, flat floored valley of the Kautz Fork, a valley that seems disproportionately wide for the narrow gorge that empties into it. It is to be remembered, however, that it received ice from other quarters, notably from the region above Pyramid Peak. There is even reason for believing that the Wilson Glacier, when at its greatest height, overflowed eastward through the low pass back of Pyramid Peak and sent part of its volume into the Kautz valley. That that valley was once completely filled with ice is amply attested by the powerful moraines that run the entire length of the great ridge above the so-called "Ramparts."

The view into the gorge of the Kautz Glacier from the heights to the east is a singularly fascinating one that would well repay the building of a tourist trail up the ridge. The entire extent of Van Trump Park with its alpine ridges, gorges, lakes and waterfalls would thus also be opened up.

Pyramid Glacier. From the summit of Pyramid Peak one overlooks a great triangular interglacier situated on a sloping platform between the deeply sunk Kautz Glacier on the east and the Wilson Glacier on the west. It bears no name, but certainly deserves one. Merely in order to give it a handle for ready reference, but without insistence upon the acceptance of his suggestion, the writer will speak of it here as the Pyramid Glacier. In the meanwhile he hopes the Mountaineers of Seattle may settle upon an appropriate appellation.

The Pyramid Glacier heads against the great cleaver that descends from Peak Success. To the east it is separated from the Kautz by a straight, mile-long ridge covered with moraine. It has a length of a mile and a quarter and its greatest width is nearly a mile. Formerly part of its névé shed into the gorge of the Kautz Glacier, but today its contributions to that ice stream are practically nil. Most of its volume used to cascade into the cirque-like valley back of Pyramid Peak. That region now is clothed in green and is one of the most picturesque timber line gardens the writer has had the pleasure to visit. It is easily accessible even now, although there is no beaten trail. It seems difficult to realize that the total number of tourists who have visited this park thus far probably does not exceed a dozen. Among its chief attractions is a perpendicular waterfall from the edge of a cliff of columnar basalt two hundred feet in height. Until last year that fall was scarcely known to anyone, and remained nameless. The name Pearl Fall was then suggested by one of the park rangers.

Wilson Glacier. (*1) The next glacier to the west is the one marked on the old government maps as Wilson Glacier, named for the topographer A. D. Wilson who accompanied S. F. Emmons on his dash to the summit (*2) a few weeks after Van Trump and Hazard had made their first ascent.

This glacier originates in a profoundly sculptured cirque under Peak Success at an elevation of 10,900 feet. It is an even four miles long and throughout its upper course averages half a mile in width. It forms the eastern member of the remarkable group of associated ice streams of which the Tahoma Glacier is the western member. The two great glaciers flow parallel to each other, separated in their middle course for over a mile by a mere row of isolated rock pinnacles, the remnants of an attenuated cleaver which is now partly submerged and over which the névés coalesce. Farther down the two glaciers abruptly part company, and cascade around a formidable pinnacled and deeply scarred fortress of barren rock, to meet again at its base, two thousand feet lower down. From Indian Henry's Hunting Ground one looks out upon this singularly magnificent glacial scene. Strange it seemed to the writer that the imposing rock mass hemmed in by the ice should not long since have been given a name. Glacier Island is the appellation he has suggested for it.

Glacier Island has an extent of nearly a square mile. So excessively steep are its ice-carved sides, however, that it is

(*1)The old names as adopted by the U. S. Geographic Board will be used by the writer pending possible reforms in nomenclature.

(*2)S. F. Emmons, The Volcanoes of the Pacific Coast of the United States, Journ. Am. Geograph Soc., Vol. IX, 1877, pp. 45-65.

MOUNTAINEERS CROSSING THE WHITE GLACIER
S. V. Bryant

Showing the great lateral morain on the west side of the glacier. July 30, 1912. This glacier is the largest, finest and longest in the United States. It extends from the summit of Mt. Rainier down the entire eastern slope to the base, averaging two miles wide and about eight miles long.

not readily accessible except to experienced climbers. The island consists really of two rock masses divided by a deep abyss. A lobe from the Wilson Glacier formerly plunged into this gulf, and connected with the Tahoma Glacier, thus splitting the island into two lesser islands. A small remnant of this lobe still exists, but it no longer reaches to the bottom of the gulch.

The south half of the island, upon examination proves to have been entirely overridden by the Wilson Glacier; the higher north half, on the other hand, judging from the greatly weathered appearance of the frail pinnacles that surround it, has never been submerged.

The Wilson Glacier in passing around the island narrows down to a width of only six hundred feet, that is, a width one-fourth of the average width which it maintains above the island. At the same time its slope is greatly accelerated. In half a mile it descends 1,400 feet. Yet the glacier does not appear to break and cascade as it does in so many places farther up.

At the foot of Glacier Island the Wilson Glacier broadens again and unites with the great east lobe of the Tahoma Glacier, the two continuing thence for a distance of three-quarters of a mile as a single mass. This mass one might at first glance not take for a glacier; so entirely concealed is it under a mantle of morainic material. But a live glacier it truly is, as one may readily discover by venturing out upon its treacherous, hummocky surface. The coarse sand and cobbles are then seen to constitute but a thin veneer, through which the clear, blue ice shines in many places. So large are the quantities of powdered rock that bestrew this extensive tract, that the wind occasionally picks them up and creates veritable dust storms with them. The writer while crossing the glacier on one occasion met with such a dust storm, and a most disagreeable experience it proved to be.

Tahoma Glacier. This ice stream is by far the largest on the southwest side of Mount Rainier. Originating on the very summit of the mountain, it descends through the great, mile-wide breach that separates Peak Success from the Liberty Cap massif. For the most part it cascades down in the form of an unbroken stream, but a portion of its mass falls in avalanches down the great precipice that extends northward and forms part of the wall of the enormous amphitheater under Liberty Cap. This amphitheater, which is second only to that of the Carbon Glacier, contributes a very considerable share of the total bulk of the Tahoma Glacier, perhaps as much as 30 per cent. Strangely, the union of its ice mass with that coming down over the cascades does not give rise to a medial moraine. It will require further investigation to determine the reason for this striking anomaly.

Farther down the Tahoma Glacier broadens to a width of slightly more than a mile, presenting an unruly, billowy surface, diversified by numerous crevassed domes and abrupt ice cascades. Approaching Glacier Island, the great stream contracts until at the west end of the island it measures only 1,700 feet across. Immediately below this point the glacier splits upon a low wedge, sending one lobe to the south and another to the southwest. The south lobe joins the Wilson Glacier under Glacier Island and thus becomes tributary to the Tahoma Fork. The southwest lobe continues by itself for a distance of a mile, giving birth to the southernmost fork of the Puyallup River. The south lobe, it may be added, is accompanied on both sides by splendidly developed lateral moraines; the moraine at the foot of Glacier Island especially is perfect and worthy of a visit.

Measured from Columbia Crest down to the end of the southwest lobe (which has an elevation of about 4,800 feet), the Tahoma Glacier is found to be exactly five miles long. Measured to the foot of the Tahoma Fork lobe it is five and three-fourths miles long.

Puyallup Glacier. The same amphitheater that contributes so generously to the Tahoma Glacier also initiates the Puyallup Glacier, the next ice stream to the north. In the center of the amphitheater rises a bold pinnacle of black rock which parts the névés and from which trails the long and exceedingly narrow rock cleaver that separates the Puyallup from the Tahoma Glacier.

On issuing from the cirque the Puyallup Glacier passes through a chute only 1,200 feet in width. A short distance below part of its mass is diverted northward to the Edmunds Glacier; yet notwithstanding this small beginning and immediate loss the Puyallup farther down spreads out to a width of three-quarters of a mile and then to a full mile, and attains a length of slightly over four and one-half miles. Its front reaches down to a level of 4,600 feet, the same level reached by the much greater Tahoma Glacier. The reasons for this anomalous state of things will be made clear on another page.

The snout of the Puyallup Glacier affords many points of interest. In the last half mile of its course the glacier describes a beautiful curve flanked by precipitous cliffs which it evidently has undercut. Just above the bend it splits upon a diminutive wedge, the little lobe thus separated hanging like a triangular tongue down a steep slope. Evidently the glacier before it had receded to its present position, used to cascade over the little wedge as a solid stream, filling the capacious amphitheater below that marks the head of the Puyallup Valley.

Edmunds Glacier. This ice stream is the shortest of the series of eleven main glaciers of Mount Rainier. It lies on the west flank between the Puyallup and Willis Glaciers, and partakes of the characteristics of both of these ice bodies. Like the Willis Glacier it originates in a shallow cirque at an elevation of about 11,000 feet. This cirque is fed by direct precipitation, by drifting and by avalanches from the steep rocky flanks of the Liberty Cap massif. In addition the glacier receives, as stated before, considerable contributions from the Puyallup Glacier.

About a mile and a half above its terminus the Edmunds Glacier splits on a narrow moraine covered ridge. The north lobe, which is the shorter of the two, is of interest principally for the strong morainic ridges that parallel it. The south or main lobe carries a great deal of debris, only a narrow lane of clear ice extending between the ever broadening moraine bands on the sides. The south edge of the glacier is shielded by a long and high cliff of columnar basalt, aptly termed the colonnade.

The total length of the Edmunds Glacier is three miles; its average width some 2,000 feet. It reaches down to an elevation of 4,400 feet.

Nameless Interglacier. On the broad platform between the Edmunds and the Willis Glacier lies a great névé field one and one-half miles long and about a mile wide. At an altitude of 8,200 feet it splits on a narrow crest, sending a small portion of its mass northward to the névé fields bordering the Willis Glacier. To the south, again, it contributes to the Edmunds Glacier. Perhaps the most interesting feature connected with it is the stream that issues from the main lobe. That stream, after cascading noisily down a steep amphitheater-like hollow, tunnels under the front of the small north lobe of the Edmunds Glacier, reappearing farther down reinforced by the melting water from that ice body.

In former times the interglacier attained much greater dimensions and coalesced with the Edmunds Glacier, just as the ice fields immediately north of it now form part of the Willis Glacier. It is to be hoped that a suitable name may soon be suggested for this beautiful interglacier, which in point of size is, next to the Paradise Glacier, the largest body of its class.

Summary and Conclusion. In making a careful study of the glaciers here described one cannot but be impressed by the fact that the summit of the mountain is not the source of all the "main" glaciers, but that cirques at relatively low altitudes give birth to a large percentage of them. Thus, of the five main glaciers here described, only two come from the summit and of these two, one, the Kautz Glacier is considerably inferior in volume to any of the cirque born glaciers. Of the entire set of eleven main glaciers of Mount Rainier, only six are summit born, to-wit, the Winthrop, Emmons, Ingraham-Cowlitz, Nisqually, Kautz and Tahoma, and five are cirque born, to-wit, the Wilson, Puyallup, Edmunds, Willis and Carbon.

The advantage of dropping the distinction between primary and secondary glaciers, on a basis of origin, is thus manifest. The real reason for abandoning Russell's system of primary and secondary ice streams, however, is of a more fundamental nature and requires further explanation.

Underlying Russell's system, evidently, is the idea that the summit regions because of their superior altitude constitute the chief gathering ground for snow, and that, therefore, they should normally feed the largest glaciers. The hollows in the interglacier tracts, on the other hand, because of their low altitude and relatively small capacity he held to be able to generate glaciers of subordinate importance only. Russell's climbs across the Winthrop and Emmons Glaciers no doubt served to impress him greatly with the vastness of these two summit born ice streams. Interglacier, on the contrary, must have impressed him by its relative insignificance. It is easy to see how his intimate acquaintance with these glaciers on the northeast side of the mountain influenced him in the formulating of his scheme.

Had he been able to extend his investigations to the west side of the mountain, most probably he would have revised his views. He would have realized that the "Wedge" between the Winthrop and Emmons Glaciers is not really representative of the interglacier tracts on the other portions of the cone; indeed that it is merely an adventitious division point far down on the mountain flank, while the other great wedges all head high up, on the ancient crater rim, as they normally should on a volcano with the geological history of Mount Rainier. He would further have realized that on the extensive and deeply sculptured surfaces of such great wedges (as those culminating in Peak Success and Liberty Cap) there is abundant opportunity for the generation of large glaciers.

In Russell's days the manner in which cirques act as catchment basins for windblown snow was but dimly understood, nor was the rôle played by the wind in distributing the snows on mountains of great altitude fully appreciated. Yet that such is the case we now positively know. The cirques and other hollows on a peak like Mount Rainier fill with snow not as the result of simple vertical precipitation, but mainly through drifting under the influence of high winds. The ridges between the hollows after every storm are quickly bared, while in the wind sheltered depressions the snows accumulate to great depths. It is herein that lies the secret of the remarkable capacity that cirques possess for the collecting of névé and the generating of glaciers.

Had these things been clear to Russell, he never would have classed the Willis and Carbon Glaciers as primary, that is, as summit born glaciers. He classed them as such because he conceived them to be fed largely by avalanches from the summit névés. That they receive such avalanches is true enough, but these accretions are not to be regarded as constituting the glaciers' main source of supply. Large and imposing though the avalanches may seem, they probably are quite subordinate in volume to the snows gathered in the cirques by drifting.

LITTLE TAHOMA
P. M. McGregor

View of the rugged peaks from the divide between the forks of the Frying Pan glacier. July 30, 1912.

The enormous amphitheater for which the Carbon Glacier is noted, Russell thought of as a sequential feature, developed by the cascading ice, and now threatening by the continued recession of its head-wall into the heart of the mountain to seriously curtail the supply of tributary summit névés. As a matter of fact the cirque constitutes the real generatrix of the ice stream, and the latter's fate does not at all hang upon the snow supply from above, as Russell thought. As long as the amphitheater catches a sufficient amount of wind blown snow the Carbon Glacier will continue to exist, even if the tributary névés on the summit were completely wiped out of existence.

The Willis Glacier is closely similar to its neighbor the Edmunds Glacier and requires no special explanation. Both ice streams as well as the Carbon must be classed as cirque born glaciers; the only difference between them lying in the vaster proportions of the Carbon's amphitheater, and these no doubt were determined by the superior size of the great hollow that originally existed in the mountain's north flank.

And now a word about another matter that even today is not generally understood. The precipitation on mountains of great elevation does not increase steadily upward all the way to the summit. As is well known to meteorologists the level of maximum precipitation is usually found at moderate altitudes, and therefore in many instances several thousand feet below the top. This is true also of Mount Rainier. The heaviest snowfall on that peak probably occurs at levels between 8,000 and 11,000 feet. For it is between those levels that the moist air strata hang and that the great storm clouds habitually form. This in itself explains why so many of the mountain's glaciers and ice fields originate low down upon its flanks, mostly at levels below 11,000 feet. It also explains another fact, which must have struck more than one careful observer, namely, that so many glaciers have a length and volume wholly disproportionate to the limited capacity of their sources. And this characterization holds for cirque and summit born glaciers alike. One need but view the slender Kautz Glacier to feel at once convinced that the small initial supply which it draws from the summit névés is unable by itself to sustain an ice stream of so great length. The tributary it receives from Peak Success of course strengthens it considerably, but it is a notable fact that the glacier even before it receives this reinforcement appears larger than it was at the start. Obviously it receives accretions midway in its course, not only by precipitation but by drifting. The very size of its tributary suggests how considerable such accretions are likely to be.

Similar observations may be made on the other summit born glaciers, only in most cases the conditions will be found more complex than in the Kautz.

Especially striking is the downward enlargement of some of the cirque born glaciers, notably the Puyallup, Edmunds and Willis. Their beginnings are insignificant, yet each of these ice streams greatly augments in volume and in dimensions in its middle course.

Thus it appears that, after all, the mountain's flanks rather than its summit constitute the principal gathering ground of snow, and it is in that fact especially that we find warrant for placing all the large glaciers of Mount Rainier, whether cirque or summit born, on a parity with each other.