THE GLACIERS OF MOUNT RAINIER.

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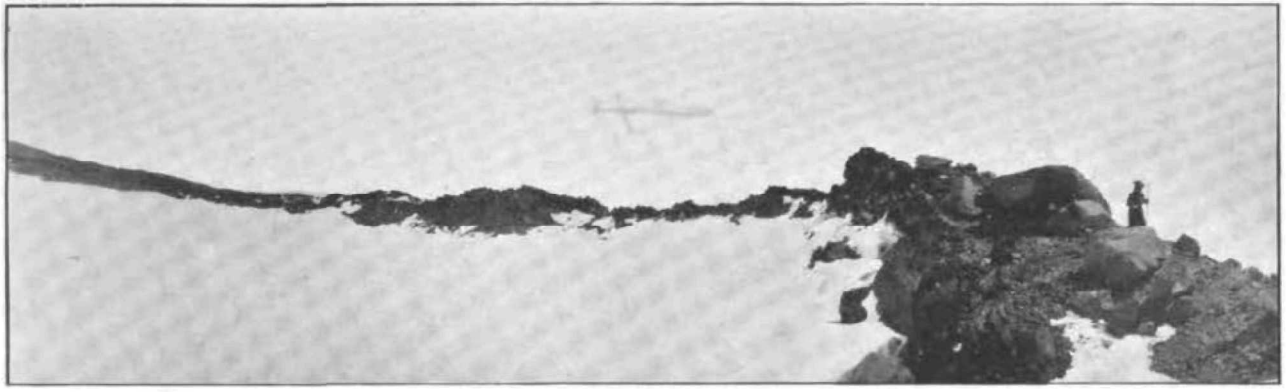
[Compiled by Alida J. Bigelow from Mr. Russell's report in the 18th Annual Survey, Vol. 2, U. S. G. S.]

The geology of Mount Rainier in its present general form shows that when in its greatest perfection it was a conical mountain, with gracefully concave sides. The upper portion of the mountain is formed to a large extent of fragments thrown out during explosive eruptions. Lava flows are also abundant, but did not greatly modify the character of the slope as determined by the falling of projectiles shot out of the summit crater.

The height of the mountain, between 15,000 and 16,000 feet, before the explosion that truncated its summit, insured the gathering of perennial snows and the formation of névé* fields and glaciers on its more elevated portions. The main topographic changes that have resulted must therefore be due to glacial action and the eroding power of streams fed by the ice.

Assuming that the peak was originally a perfectly symmetrical cone with smooth, even sides, and that the névé formed a uniform covering over the upper third of its surface, the downward flow of the névé would be equal. Many disturbing conditions come in, however, in the case of a peak like Mount Rainier, composed of loose agglomerate and lava sheets. Irregularities in the surface of the cone, erosion by streams flowing from the ice, unequal drifting of the snow, as well as unequal melting, owing to variations in exposure

* Neve is the granular snow-ice, before the formation into solid glacial ice.



CRATER OF MOUNT RAINIER Photo by Asahel Curtis

MOUNTAINEERS ON THE SUMMIT OF MOUNT RAINIER

Photo by Asahel Curtis

IN AN ICE CAVE UNDER COLUMBIA CREST

Photo by Asahel Curtis

PLANTING OF THE A.-Y.-P. E. FLAG INSIDE THE CRATER

on the western and southern sides, would lead to the gathering of the ice into more or less definite streams. Individualized ice streams once established would hold their positions, and by their erosion would sink deeper and deeper into the rocks. From the extremity of each glacier a stream fed by the melting ice would carve a gorge or canyon, leading to rivers on the plain below. As the ice gathered in well-defined streams, melting would be retarded and the glaciers constantly extended farther and farther down the water-cut gorges. In this manner what may be termed primary glaciers would originate from the dividing of the descending névé. As the glaciers deepen their beds they sink into the mountain and are more completely sheltered from the sun, thus tending to perpetuate their own existence. Between the primary glaciers there would be portions of the lower slopes of the mountain left in relief by the excavation of the valleys between them. These V-shaped masses pointing up the mountain would form wedges, against which the descending névé would divide to form primary glaciers. The Wedge and Little Tahoma are typical examples of such wedges.

As is well known, the erosive action of a glacier, other conditions being the same, depends on the gradient of its bottom. Judging from the present condition of Mount Rainier and other similar isolated peaks on the Pacific Coast, it appears that the most intense erosion occurs in a zone about half a mile broad where the primary glaciers become distinct ice streams. In this zone the glaciers excavate canyons, and thus increase the slope of the central mass of the mountain above the extremities of the V-shaped residual masses, on its lower slopes. Tho heads of these valleys tend to become amphitheaters. The cliffs encircling an amphitheater in which a glacier has its source, gradually recede, owing to the disintegration of the rocks in the great crevasse, termed a bergschrund, which is formed

near where the upward sloping névé meets the rock wall inclosing it.

The extension of the amphitheaters at the heads of the glaciers renders the sides of the dome more and more precipitous as glacial erosion progresses. Carbon Glacier, flowing northward and having its amphitheatre sheltered from the noonday sun, has excavated a great recess or cirque* in the side of the mountain, while the glaciers on the south side of the peak have scarcely more than begun to form similar recesses.

The primary ice streams on Mount Rainier, in the order of their occurrence, beginning on the north side of the mountain and going about it toward the east, south, etc., are as indicated on the accompanying map, the Carbon, Winthrop, Emmons (or White), Ingraham, Cowlitz, Nisqually, Kautz, Wilson, Tahoma, Puyallup, Edmunds and Willis (or Mowich) Glaciers. The secondary streams, or interglaciers, as it is convenient to term them, in the order just stated, are Interglacier, Frying Pan, Little Tahoma, Williwakas, Paradise, Van Trump and others not named. A former extension of the interglaciers and the previous extension of true glaciers, where only deep snow accumulations now occur, is shown by the polish and grooves on the rocks, below the positions they occupy.

Carbon Glacier.

The amphitheater in which Carbon Glacier has its source is the largest excavation that has been made in the sides of Mount Rainier. The snow on the less steep slope above the cliff leading to Liberty Cap, creeps down to the verge of the precipice and then breaks off and forms avalanches, which descend to the glacier below. [Avalanches were very common here, and could be plainly seen from the Mountaineer Camp, 1909.] Carbon Glacier in reality has no true névé at present,

* Cirque, an amphitheater-like valley head.

except the snow-covered area, just mentioned, above the summit of the cliffs encircling its amphitheater. The gathering ground of the glacier has been decreased by the extension of the amphitheater until it is but a fifth or a tenth of its original extent. This glacier is still enlarging its amphitheater, and if the process does not check itself by decreasing the area on which snow for the supply of the glacier accumulates, will cause such a recession of the cliffs at its head that the central dome of the mountain will become broken.

The wall of rock rising above the head of the glacier is about 4,000 feet high. On this vast precipice little snow accumulates, but on its summit there is a vertical cliff of stratified névé snow about 200 feet high. [This wall of rock is called Willis Wall. See Plates 17 and 25.] At the outlet of the ampitheater the snow, still having the characteristics of a névé, is much crevassed, especially where it passes over bosses* of rock on the floor below. The glacier descends a moderately steep slope on leaving the amphitheater, flows for a mile and a half with a very gentle grade, and then goes over the edge of a precipice and descends a steep slope to its end. The alternate breaks, and level reaches resembling a great stairway are not a novel feature, as is well known, but a characteristic of many alpine glaciers, and indicate similar features of the rock surface beneath. A glacier cuts back its beds from one ice fall to another, in much the same way that a cascade of a stream recedes. [Plate 17 shows Carbon Glacier and its much crevassed condition on leaving its cirque or amphitheater.]

Opposite Andesite Cliff, Carbon Glacier is about half a mile broad, but it soon increases to nearly a mile in width, and maintains this increase all the way to the brink of the steep descent, a mile and a half below.

Down-stream, the glacier is progressively more and

* A boss is a protruding mass of harder rock in the glacier bed.

more deeply covered with stones and dirt. Below the beginning of the steep descent leading to the terminus no ice can be seen in a general view. The end of Carbon Glacier was seen by Willis in 1881. At the time of our visit the glacier had retreated about 100 yards, as nearly as could be estimated, above the position it occupied thirteen years previous, and the precipice at its terminus had become less steep.

[The Mountaineers' Club built a trail, easily used by pack train, up this face of Carbon Glacier in 1909. This shows that in the thirteen years since Mr. Russell reported, there has been much greater wasting away of the ice. See Plate 18.]

A recent lowering of the surface of the glacier is recorded by abandoned lateral moraines. These are conspicuous along each side of the glacier. On leaving the glacier on either side and climbing the fresh slopes of morainal material bordering it, one finds similar parallel ridges, each of which is clothed with forest trees. These older moraines are in several instances higher than the most modern ones, and show in general a progressive lowering of the surface of the ice as the width decreased. When the earliest pair of moraines were formed it was about a mile broader and its surface about 250 feet higher than now. Whether the valley was ever more deeply filled with ice than is recorded by these old moraines remains to be determined. [These elevated lateral moraines are common at the sides and above most of the glaciers on Mount Rainier.]

At the foot of the steep descent Carbon River emerges from a cavern in the ice, a roaring torrent, heavily encumbered with boulders. [Plate 18.]

Winthrop Glacier.

The névé of Winthrop Glacier extends to the summit of Mount Rainier. A part of the snow that ac-

WHITE GLACIER, THE LARGEST ON MOUNT RAINIER Photo by Asahel Curtis

Photo by Asahel Curtis

MOUNTAINEERS ON INTER GLACIER, ST. ELMO PASS IN CENTER, GLACIER BASIN AT RIGHT

Photo by Asahel Curtis

RUSSELL PEAK

SPRAY FALLS

cumulates in the great summit crater between Crater Peak and Liberty Cap flows eastward down the precipitous slope of the central dome, covering all that side of the mountain. The eastern side of the mountain is more heavily snow covered than any other portion, mainly for the reason that the prevailing westerly winds cause the snow to be deposited there in greatest abundance. Near the lower limit the névé is divided by two rocky promontories known as The Wedge and Little Tahoma. Their prow-like rock masses divide the névé into three primary glaciers—the Winthrop, Emmons (or White) and Cowlitz.

The névé of Winthrop Glacier descends below The Wedge and terminates above timber line at an elevation of approximately 8,000 feet. Below the lower margin of the névé the solid blue ice of the glacier proper, in places heavily covered with *debris* extends far down the valley, between rugged mountains, and ends at an elevation of between 4,000 and 5,000 feet. [Winthrop Glacier carries the largest rock masses of any glacier on Mount Rainier. This is probably due to the great supply of loose rock at the edge of Willis Wall. See Plate 19.]

From the ends of the glacier one branch of the White River flows out as a swift, turbid stream, heavily loaded with coarse *debris*. One of the characteristic features of the glaciers about Mount Rainier is the occurrence of well-marked domes, the summits of which are commonly fractured so as to produce radiating crevasses. Several of these domes occur in Winthrop Glacier, both in the névé portion and in the glacier proper. The margin of the glacier is heavily moraine covered and much broken by crevasses. In places it is impassable.

The extremity of the glacier flows past a bold rock dome, which was formerly covered with ice, and at a later stage, as the glacier receded, divided it into two

branches, the eastern being the broader. The ice has here shrunk away from the moraine, and is now fully 100 feet below its crest.

Emmons (or White) Glacier. [Plate 20.]

[White Glacier is the longest in the United States.]

Below The Wedge and Little Tahoma, Emmons Glacier is a well-defined ice stream, about five miles in length, with bold, rocky cliffs on each side. The glacier becomes heavily charged with debris along its borders from the adjacent cliffs, and in the lower portion of its course is completely covered with stones and dirt on either side. These lateral moraines become broader and broader toward the terminus of the glacier, leaving a tapering lane-like tongue of clear ice between, but before the terminus is reached the ice over the entire surface is concealed by a continuous sheet of brown and barren debris.

The tongue of clear ice near the extremity of the glacier is some two or three miles long, and much of the way about one-third the width of the valley.

Emmons Glacier, like all the other primary glaciers on Mount Rainier, is evidently wasting away and its terminus receding.

Ingraham Glacier.

The portion of the névé descending the east side of the central dome of Mount Rainier, to the right or south of Little Tahoma, forms a primary glacier of an abnormal type. This well-defined ice stream does not descend the mountain slope in a direct course, but is deflected southward or becomes tributary to Cowlitz Glacier.

On approaching its junction with Cowlitz Glacier, Ingraham Glacier descends a precipice about 800 feet high and forms a fine ice cascade.

Cowlitz Glacier.

The Cowlitz Glacier, above where Ingraham Glacier joins it, expands somewhat and occupies an irregular depression having something of the features of an amphitheater. The slopes at the head of the depression are so sharp that the snow descends in avalanches.

The portion of Cowlitz Glacier below Ingraham Glacier is enclosed by bold cliffs and is well defined. There is less evidence of shrinkage along its sides than in the case of the other glaciers examined. A sharp-crested lateral moraine is evidence, however, of a recent lowering of the surface of at least 75 or 100 feet.

Nisqually Glacier.

Nisqually Glacier heads in two névé fields, which occupy what may be termed incipient amphitheaters, situated below the level of Gibraltar. The easterly névé, the one nearest Gibraltar, however, is fed by two snow streams, which endure through the summer and form ice cascades on which avalanches frequently occur.

This glacier narrows to a well-defined stream to the west of Paradise Park, and at its terminus there is an archway from which Nisqually River rushes out.

[Mr. Russell did not study Kautz, Wilson, Tahoma, Puyallup and Edmunds Glaciers, and so no report is given of these.]

Willis (or Mowich) Glacier.

On the northwest side of Mount Rainier and at the head of the deep, narrow valley through which the north branch of the Mowich River flows, is a glacier known as the Willis (or Mowich). It has many of the features of the primary glaciers already described, but is of small size, and one may see all its characteristic features in a single day's excursion.

The entire distance from Liberty Cap, where the snow accumulates to the extremity of the glaciers, where it melts away, is approximately five miles. The breadth of the glacier where its borders are best defined, about a mile above its terminus, is approximately 3,000 feet.

At the head of the canyon there is a steep ascent to the summit of the mountain resembling the higher and more precipitous cliffs at the head of Carbon Glacier. There is a noticeable enlargement of the canyon near its head, but it is not extensive enough to be classed as an amphitheater. From the summit of Eagle Cliff—where may be seen the most magnificent of the views about Mount Rainier, and in fact one of the most sublime pictures of noble scenery to be had anywhere in America—the whole of Willis Glacier, from the snow fields that give brilliancy to Liberty Cap down to the dirt-stained and crevassed extremity of the ice stream, is embraced in a single view.

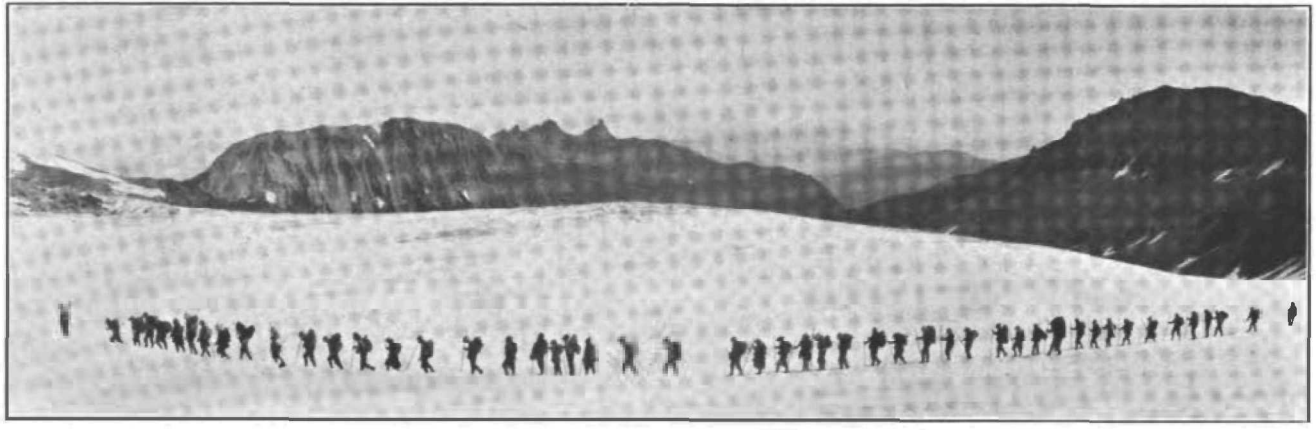
From Eagle Cliff the manner in which Willis Glacier is divided at its extremity into two moraine-covered tongues of ice is a noticeable feature. The bold rocky eminence that causes the division rises steeply in the center of the valley to a height of fully 1,000 feet, and is clothed on its down-stream side with forest trees.

The retreat of the glacier within recent years has been accompanied by a lowering of its surface, as is plainly recorded by fresh-looking ridges of debris along its border. On the northern side of the glacier, for a mile above the ice fall of 400 feet, there are three well-defined abandoned lateral moraines.

Interglaciers.

The interglaciers were formerly more extensive than now, and much of the beauty of the park-like regions in the neighborhood of the upper limit of timber growth is due to the changes they made in the relief of the

WINTHROP GLACIER, SHOWING ST. ELMO PASS. Photo by Asahel Curtis



CROSSING THE WINTHROP GLACIER Photo by Asahel Curtis

Photo by Asahel Curtis

NOSE OF THE CARBON GLACIER

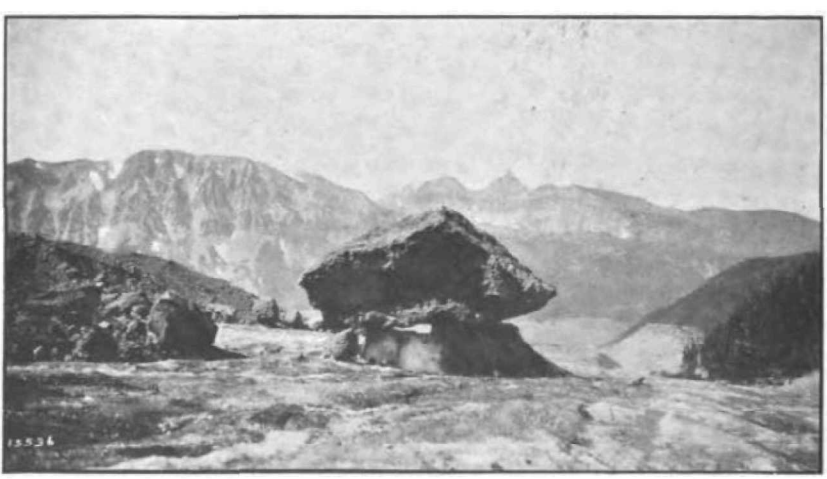


Photo by Asahel Curtis

HUGE ROCKS CARRIED DOWN BY THE WINTHROP GLACIER

mountain side, both by rounding and smoothing the rocks over which they flowed and by heaping moraines upon them. [See Plate 2.]

Many of the crags and pinnacles which give diversity to the scenery on the steep mountain slopes, like the Guardian Rocks near Spray Park, Gibraltar and the numerous crests near it, and other similar crags in Henry's Hunting Ground, etc., are remnants spared by the glaciers which once enveloped nearly the entire surface of the mountain, but still in their deeper portions flowed in most instances in well-defined channels. [See Plate 3.]