Behind the Scenery of
MOUNT RAINIER NATIONAL PARK

— Howard R. Stagner

BEHIND *the* SCENERY *of* Mount Rainier National Park

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FOREWORD

THE contemplation of a landscape of exceptional beauty is in itself a sufficient reward for a visit to a National Park. The awesome beauty of a Grand Canyon, the mystery of erupting geysers, the towering sharpness of a Teton Range, and the dominating bulk of a Mount Rainier with its gleaming glaciers are forces which impinge deeply upon the consciousness and sense of beauty. For many, too, these works of Nature excite a compelling curiosity. How did these features come into being? What natural forces are operating even today to modify the scenery? What are the trees, the flowers, the mammals and birds that dwell within these areas? An intimate acquaintance with Nature and her ways enhances and augments the pleasures of contemplation. This booklet, the second of a series published by the Mount Rainier National Park Natural History Association in cooperation with the National Park Service, attempts to provide some of the background for the fullest enjoyment of the Mount Rainier scene.

PRESTON P. MACY
SUPERINTENDENT
Mount Rainier National Park
United States Department of the Interior.

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COVER:

Reproduction of Water-Color Painting by Park Ranger D. Molenaar

COLOROGRAPHY
North Pacific Bank Note Company

PREFACE

Snow-capped mountains, gleaming glaciers, and cascading rivers; flower meadows, deep forests, and the birds and mammals that dwell therein; cloud progressions, drifting snows, transitory sunset colors, and shimmering reflections—all these are implied in the one word "Scenery." Each of these landscape elements is often considered a thing unto itself—something quite unrelated to the balance of the scene. But all are, in fact, related and interdependent, not only in that taken together they enter into the composition of an inspiring scene, but as well in origin, and in the very fact of being. Behind the total scene is the same long series of events—dynamic earth movements which gave elevation to the mountains, volcanic eruptions, the sculpturing of the landscape by rivers and glaciers, the weathering of rocks to form soil. These are geologic events, and they do more than merely explain the existence of a mountain, park, or canyon. They have established the conditions under which the flowers, forests, birds, mammals, and all other life forms exist. The plants and animals, as well as the peaks, lakes, and valleys, are a part of the scenery, and they, too, have a geological background. Behind the scenery is geology, and the pages which follow attempt to provide this background for Mount Rainier and its environs.

CHAPTER I

The Setting . . .

Anticipation, in this day of lurid advertisement and natural color photography, often transcends realization. "But, it doesn't come up to my expectations," is a remark often uttered upon the first view of one of Nature's spectacles. This is not said of Mount Rainier, for no matter how completely the visitor to the Northwest has crammed himself with information, no matter how many full color photos he has studied, his first view of "The Mountain" eclipses all expectations. The massiveness of the ice-clad peak, its dominant position among the lesser peaks of the Cascade Range, and its beauty of form and of setting by far surpass the most fervid anticipations of natural beauty.

From the shores of Puget Sound, Mount Rainier, 50 miles to the southeast, seems to rise directly from sea level, and lifts its glistening summit 14,408 feet into the atmosphere. In reality it rests upon, and covers approximately 100 square miles of the Cascade Range, mountains which themselves possess such boldness of relief as to rank them high among Washington's scenic attractions. In the vicinity of Mount Rainier the Cascade summits project upward nearly a mile and a half above the lowlands of the Puget Sound basin; but so many of the peaks and ridges stand so nearly equal in elevation that in the distant view they merge and coalesce to form what appears to be a high plateau. Mount Rainier, therefore, rests upon what seems to be a high, green-forested platform.

For a truer picture of both The Mountain and of its neighboring Cascade peaks, climb one of those Cascade summits nearer the base of Rainier. Pinnacle Peak in the Tatoosh Range of the Cascades, seven miles south of Mount Rainier, is just right for this purpose. From here the Mountain gains in its appearance of height and mass, and at the same time the surrounding Cascades upon up into a bewildering array of peaks and ridges, mountain parks and canyons. All of the features, both of Mount Rainier and of the Cascades, are thus revealed in full detail and in true perspective. Pinnacle Peak is itself no mere foothill. Its summit, 6562 feet above sea level, rises precipitously over 1500 feet above Tatoosh Creek at its base, and some 3500 feet above the Nisqually

River canyon less than three miles away. Yet Mount Rainier lifts its summit nearly a mile and a half still higher, and its massive slopes completely fill the horizon through an angle of nearly 90 degrees. Think of that—a Mountain so massive that, although you are nearly seven miles from its summit, it interposes its mass through nearly a fourth of the entire horizon.

The cone-like contours of Mount Rainier suggest its volcanic origin, but the cone is by no means a perfect one. The summit area is broad-shouldered, its sides are deep-cut by canyons and amphitheater-like basins of huge proportions. Great rock masses stand out in bold relief above the mountain flanks, or course downward, rib-like, from summit to base. The lower slopes of The Mountain, somewhat over-steepened by glacier erosion, are inclined upward in sweeping curves, flattened toward the base, steeper as they approach the summit area. Then, abruptly the summit dome rounds off the profile.

A cap of permanent ice and snow covers the summit's area. The ice spills far down the flanks of The Mountain by way of several glaciers, and reaches a minimum elevation of less than 4,000 feet. During the winter and spring the entire mountain, except for the sharpest projecting rock masses, is covered completely by snow, but by late summer the new snow has melted. At such times much bare rock is exposed below the summit ice cap, and on the interglacier areas. During this time the glaciers, permanent bodies of moving ice, have their boundaries sharply defined. But at the same time the lower portions of these ice streams assume a dirty appearance as the melting snow and ice reveal the many years accumulation of rock debris on the glacier surface.

Considering now the portion of the Cascade Range which surrounds Mount Rainier, there are three features of this landscape that command attention—three major divisions of the topography —(1) the summit peaks and ridges, (2) the mountain parks, and (3) the valleys and canyons.

Imagine a plateau with a rolling surface standing between 5000 and 6000 feet above the sea. Place here and there on that surface a series of short mountain ranges and individual peaks standing 2000 feet or so still higher. Then place The Mountain in its proper place, covering about a hundred square miles of this plateau; and next cut deep canyons radiating outward from The Mountain and sunk two to three thousand feet below the plateau surface. Space these river canyons, and their shorter, sharper tributaries so that fragments of the plateau are left as benches and mountain parks. You will have a replica of the gross features of the Mount Rainier landscape.

The mountain parks, considering the ruggedness of the summit peaks and ridges of the Cascades, and the depth and abruptness of the canyons, are somewhat surprising and incongruous landscape features. Broad and somewhat rolling or flattened areas as much as two square miles in area, some of them form the divides between the river canyons. Grank Park, Indian Henry's Hunting Ground, Spray Park, Sunset Park, and Mazama Ridge are of this nature. Others, such as Yakima Park, Paradise Park and numerous smaller parks are benches, bounded on one side by the deep-cut canyons, and on the other by the superimposed ridges of the Cascade Mountains.

Glacial rivers radiate in all directions from the lower slopes of Mount Rainier. These, as they traverse the Cascade forelands, merge to form the Cowlitz, White, Carbon, Puyallup, and Nisqually Rivers. They carry Rainier's run-off into Puget Sound and the Columbia River, forming a radial pattern of outflowing rivers. The exceptions to this rule are the rivers which start on the east side of the volcanic mountain and have their initial direction of flow toward the Cascade Crest. The White River thus is deflected from a northeastward course, and flows north parallel to the Cascade Range before turning westward into Puget Sound. Likewise, the Cascade Crest turns the Ohanapecosh, Stevens, and Muddy Fork Rivers southward to form the Cowlitz River. Between Mount Rainier and Mount Adams, it finally swings westward to the Columbia.

All of the large rivers are deeply entrenched within long, sweeping, steep-walled but broad-floored canyons. In the lower courses there are but few irregularities to interrupt the smooth flow of these streams, but as the headwaters are approached the valleys become increasingly steeper and more irregular. Each large river has its source in a glacier which fills the upper two to five miles of its canyon.

The smaller canyons, carrying the tributary streams into these major rivers, contrast decidedly with the canyons into which they empty. Heading in the mountain parks high above the canyons, these tributary streams may flow comparatively quietly for some distance over the parks before plunging abruptly or cascading downward to the main stream levels. The larger of these tributaries, where the descent is made, are themselves deeply entrenched, but the smaller ones have succeeded in carving only shallow, but narrow, sharp, "V" shaped trenches down the main canyon walls. Many of the waterfalls of the park are located on these tributary streams along the course between mountain park and canyon bottom.

In sharp contrast to the low relief of the mountain parks, and to the smooth, regular contours of the major canyons, the jagged and irregular peaks of the Cascade summits project from one to two thousand feet above the park levels. The sharp, serrate profiles of the Tatoosh Range or the Mother Mountains, the Cowlitz Chimneys or the Sourdough Range give these summits a remarkable resemblance to the glaciated peaks of the Rocky Mountains of Colorado, Wyoming's Grand Teton Range, and to the Sierra Nevada of California.

While examining the major divisions of the landscape, the lakes of the park also should be observed. Mount Rainier's lakes are small, and most of them are precariously situated, seemingly as high as possible above the major canyons into which they drain. For example, Reflection, Bench, Snow, Mystic, Tipsoo, and Owyhigh lakes are very near the stream divides, almost on the headwaters of their respective valleys. The larger lakes, such as Lake George and Mowich Lake, rest in large amphitheaters, well up the mountain sides. Others, like Golden Lakes, Mirror Lake and numerous small pools, are in the high-level mountain parks. The shores of lakes below 5000 feet are fringed by forests of fir, hemlock, and Douglas fir, but those of higher elevations stand fully revealed on the meadows amid the scattered groups of alpine trees, or beneath the barren crags above tree line.

Mount Rainier National Park, then, may be considered a high plateau whose evenness is broken by the surmounting Cascade summits, and whose flattened character has been half erased by the cutting of a fretwork of deep canyons. Superimposed over all is Mount Rainier, mightiest of the fire peaks of the Northwest, bearer of the Nation's greatest glaciers.

CHAPTER II

The Foundation . . .

A full-grown mountain range forms the base of Mount Rainier, and the towering bulk of this whitened volcanic peak robs these lesser mountains of the attention they deserve. There was a time when the Cascades were unrivaled, for The Cascade Range is older and was formed much as it appears today, long before Rainier grew to its present dominant size. The Cascades are important in the story of Mount Rainier. Not only are they responsible for the first four to seven thousand feet of Rainier's height, but their bold profiles, flattened parks, and deep canyons compose an altogether fitting environment for The Mountain, an essential component of this scene of wild charm.

Three things we should know about these mountains if we are to understand the meanings of the modern landscape, and are thus to reap the fullest measure of satisfaction in the contemplation of that scene. We need to know something of the materials out of which these mountains are built. We should know how and when this land mass was lifted so high above its surroundings, and finally, we need to know how this uplifted land was sculptured into its present form.

Picture in your mind's eye western Washington as it must have appeared some 60 million years ago. There was no Cascade Range, and the Baker, St. Helens and Rainier volcanoes did not exist at that remote time. Western Washington was a flat-lying land, close to sea level. In fact, the relief and the elevation of the land were low enough so that each downwarping of the earth's crust permitted the waters of the sea to flood much of western Washington. When the land was depressed, the shore line advanced eastward as far as the foothills of today's Cascade Range. At times of uplift, it retreated to the west, even beyond the modern

THE SEQUENCE OF EVENTS

EPOCH	EVENTS
RECENT	Vegetation advances behind the retreating glaciers to clothe The Mountain. Volcanoes approach dormancy. *Ten thousand to twenty thousand years ago.*
PLEISTOCENE	Glaciation of the Cascade Mountains, the Volcanoes, and the Puget Sound basin. The main period of volcanic eruptions. *One to two million years ago.*
PLIOCENE	The Cascade volcanoes began in late Pliocene. The uplifting of the Cascade and Olympic Mountains and the beginning of mountain sculpturing. *Twelve million years ago.*
MIOCENE	Destruction of the Miocene mountains by erosion. Intrusion of the Snoqualmie granodiorite. Uplift of mountains extending from San Juan islands and northern Olympic Peninsula southeastward into the Cascade area. Keechelus breccias, tuffs, and lavas laid down over most of the present area of the Cascade Mountains. The Columbia River basalt flows covered over 200,000 square miles of eastern Washington, Oregon, and southern Idaho. *Thirty million years ago.*
OLIGOCENE	The land areas subjected to minor uplifts and erosion. *Forty million years ago.*
EOCENE	The Puget Series of sandstones, shales, and coal beds deposited in basins and on deltas of west flowing rivers which discharged into subsiding embayments. Western Washington a lowland, with the seas advancing eastward as far as the present foothills of the Cascade Range. *Sixty million years ago.*

Rock formations of earlier geologic periods unknown in the Cascade Mountains of the Mount Rainier area.

coast line. This ebb and flow continued for, perhaps, half the total time allotted to our story, but each advance of the sea fell somewhat short of earlier floodings until, with the uplifting of the Cascade and Olympic Mountains, sea waters were driven finally from the land.

THE ROCKS

Eastward from this fluctuating, pulsating shore line, a broad, rolling somewhat hilly plain stretched toward higher hills and low mountains on the distant horizon. At times rivers spread thick layers of sand and muds in the shallow valleys. Occasionally thick accumulations of dead and decaying plants were buried beneath these sediments. Much later the sands and muds were solidified into sandstone and shale, and the plant accumulations were changed into coal beds. Today, this coal-bearing rock formation, called the Puget Group, is exposed along the Cascade foothills, and may be seen along the Carbon River in the northwest corner of and beyond the boundaries of Mount Rainier National Park. It is here approximately 10,000 feet thick. The coal deposits of the formation gave the name to Carbon River.

There was some volcanic activity even during these earlier times, but scarcely sufficient to predict the widespread and long continued volcanic events that were to follow. The grand scale volcanism began, not in the present mountain areas but in eastern Washington, Oregon, and southern Idaho—east of the Cascades. Thousands of cubic miles of black, basalt lava, issuing from fissures in the earth, flowed in widespreading, overlapping sheets to cover over two hundred thousand square miles of territory. The Columbia River Plateau, east of the Cascades, is thus built up of numerous basalt lava flows.

The scene of volcanic activity then shifted toward the west, and there followed the erupting of volcanic rock and the flowing of lavas over a large part of what is today the Cascade Range. Showers of volcanic ash, and pumice, together with eruptions of cinder-like fragmental lava, first piled up a thousand feet deep or more, and were in turn covered by thick flows of lava. The rock formation thus created is known as the Keechelus series, and it constitutes by far the most important and most common rock of the Cascades in the vicinity of Mount Rainier. Its formation doubtless required a long interval of time, but its exact time of beginning and of ending are unknown. The lower portions of the Keechelus rocks, consisting largely of the consolidated fragmental volcanic ejecta, are best exposed northeast of Mount Rainier in Glacier Basin and above Summerland. The later lava flows, whose general appearance would suggest that they might not be much older than the earliest lavas from the Mount Rainier volcano, today form the upper slopes and cliffs of Tatoosh Range, Mother Mountains, Mount Wow, and other Cascade ranges.

There was yet another seething, hot, volcanic invasion—but one which had no immediate major effect upon the surface features. Sometime after the formation of Keechelus andesites, and for a distance of a hundred miles or more beneath the present Cascades, there occurred an injection of liquid magma which, by melting, stoping, and pushing aside the older rocks, emplaced itself considerably beneath the surface to form an immense, irregular body of light-colored, coarsely crystalline granodiorite rock. Today we see this igneous rock body only where Rainier's canyons have cut downward through the Keechelus, or through the Rainier lavas, to expose it to view. In the bottom of Paradise River valley, in the Nisqually Canyon below the glacier, and in White River canyon below Emmons Glacier are perhaps the best places to observe this granite-like rock.

Thus, three types of rocks make up the Cascade Mountains around Mount Rainier's base; (1) the earliest, the Puget group of sandstones, shales and coal beds; (2) a thick deposit of volcanic ash, breccia and lava called the Keechelus formation and (3) a coarsely crystalline, granodiorite which was injected into the other two. Of these, within Mount Rainier National Park, the Keechelus formation is by far the most important.

LIFTING THE CASCADE RANGE

Meanwhile earth stresses were developing in western Washington. The first manifestation of these occurred during the time the Keechelus rocks were forming, and resulted in the uplifting of mountains trending southeastward from the San Juan Islands and northern Olympic Peninsula into the area of the present Cascades. Subsequently these were destroyed by erosion so that today only the root structures of these mountains remain as folds and fractures in the older rocks, principally north of Mount Rainier. The important mountain-making events were later, and began during late Miocene or Pliocene times.

The earth disturbances which finally lifted the Cascades, and as well the Olympic Mountains, were not sudden, catastrophic movements, lifting the mountains, so to speak, over night. Rather the total uplifting was accomplished over a very long period, and represents the total of innumerable very small movements. Perhaps, for the most part, these mountain-making movements were not much greater than the minor shiftings which even today occasionally cause earthquakes. It would not be wrong to say that the Cascades are not yet stable, and that the process of uplift or readjustment is still in progress.

The total effect of these small but numerous earth shiftings was to lift, from one to 8000 feet above sea level, a segment of earth's crust, 50 to 100 miles wide, and some 700 miles long. The uplift alone would have resulted, not in the jagged, incised, Cascade Mountains of today, but would have produced a broad, somewhat flattened plateau, with steep sides outlining the upward folds and faults along its borders.

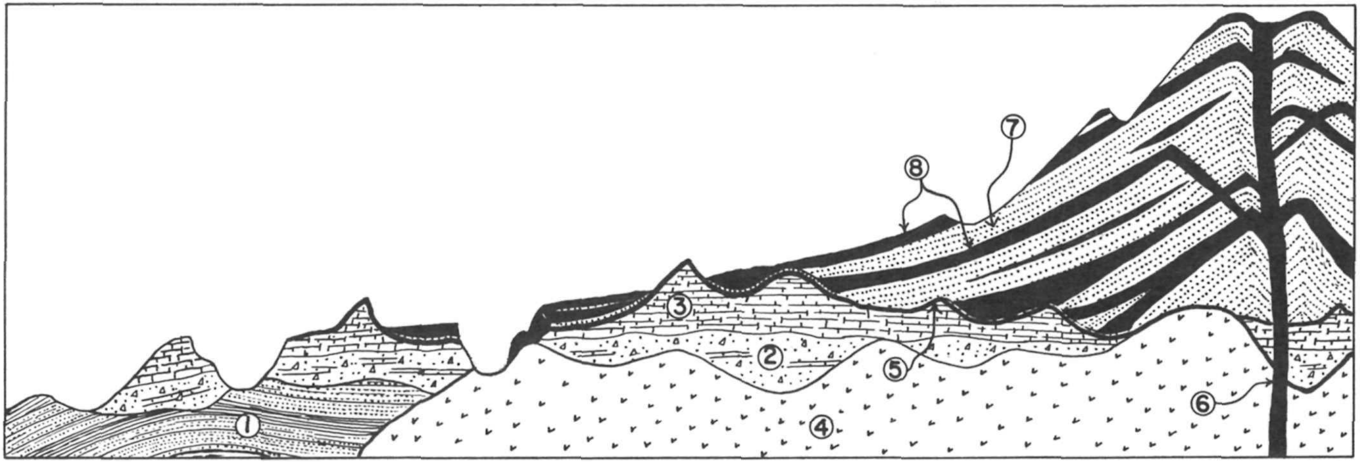
SCULPTURING THE CASCADES

There was never an actual Cascade plateau. As soon as any area is lifted above its surroundings, agents of erosion immediately attack it in an effort to restore flatness and evenness. As the Cascade mountain block began to rise, immediately the atmosphere, the winds, and the quickened rivers began their work. Exposed rock, attacked by weathering, became soil and sand. Gullies became canyons, ever deepening as the mountain block rose. Large rivers acquired tributaries, the tributaries captured smaller ones, and these in turn were fed by slope-washing and gully-cutting run-off from rains and melting snows. Among this anastomosing system of river trenches were left the highlands, individual peaks, and the high, interstream ridges.

How much of this erosion had been accomplished before the Rainier volcano first came into existence is not known. But, by tracing the lowest, basal lavas of Rainier around the mountain, downward into the canyons, upward over the intervening ridges, we do know that Rainier erupted upon and covered a mountain topography that was quite rugged. The lowest places where lavas from Rainier are found are in Stevens Canyon, and near Longmire, at elevations of about 3,000 feet. The Keechelus andesites, on the other hand, are found as high as 7,000 feet, while at St. Elmo Pass the pre-Rainier granodiorite is found as high as 7,500 feet.

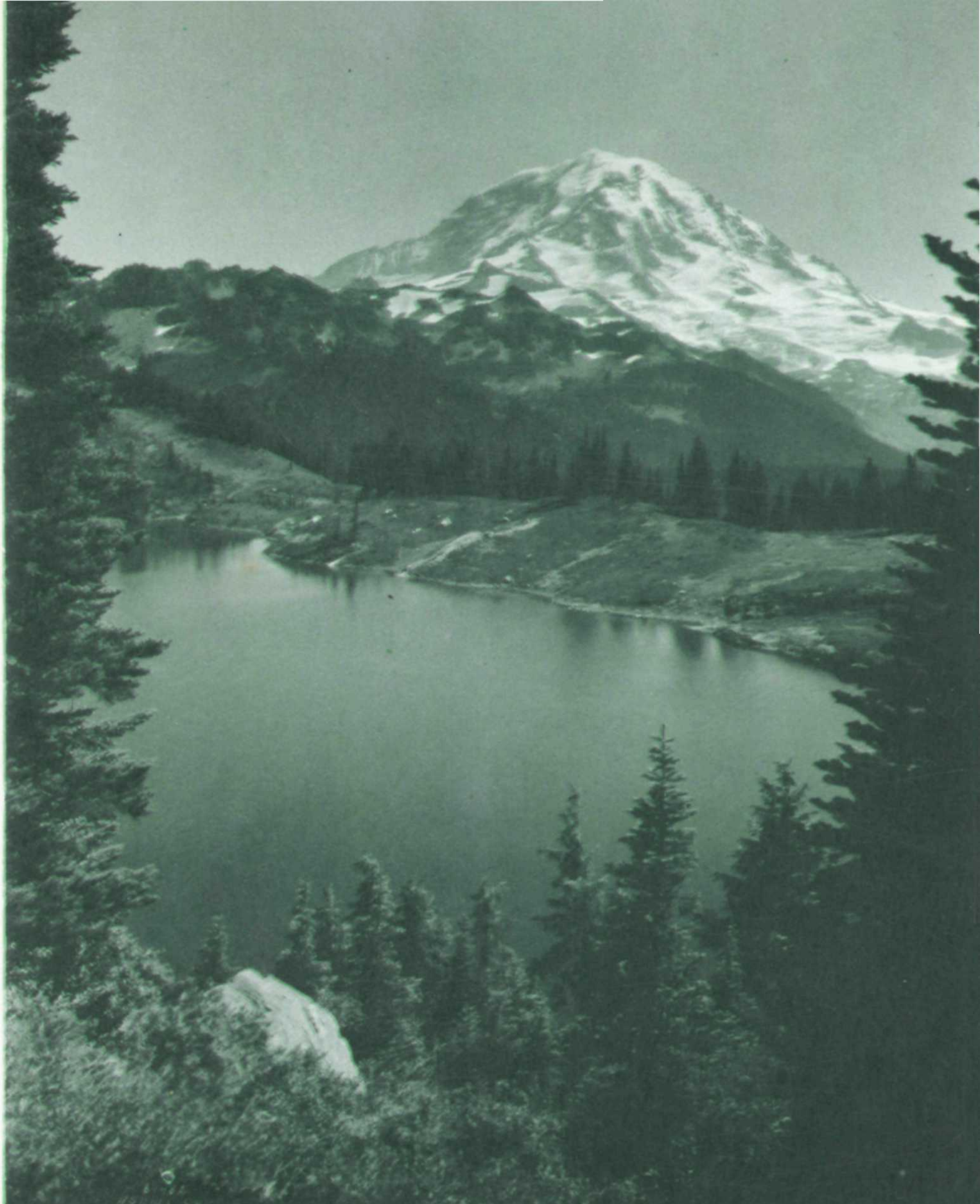
Thus the Rainier lavas covered and concealed mountains that stood 3,500 feet above the canyons. Part of the canyon deepening took place even during the life of the volcano. Nevertheless, the canyons and valleys, and the individual ranges of the Cascades were blocked out, much as they are today, before the Rainier volcano came into being. The finer details of the sculpturing were accomplished at a later time. The carving out of the mountains began with the first uplift, and has never ceased. The rate at which the mountains are being carved and worn is as great today, perhaps, as at any time in the past.

Some of the broad valleys which were formed in the Cascades before the eruptions of the Rainier volcano, more recently have been deepened by rivers and glaciers. In some cases portions of the older valleys have been left as benches and small parks, their surfaces strewn with volcanic ash and pumice, or with the irregular uneven deposits of later glaciers. The larger parks or flats such as Grand Park, Mazama Ridge, and Burroughs Mountain, however, had a different origin. These, although they now may be buried many tens of feet deep by ash and pumice, essentially represent the surfaces of lava flows, Rainier lava flows, or the latest Keechelus flows. These flows, lying today between adjacent stream canyons, escaped erosion and retained their flattened character. Later they were covered with a protective layer of porous ash and pumice. As a rule they show few signs of erosion because the rain and melting snow waters percolate downward through the loose, porous volcanic ash. A blanket of ash, cinders and pumice may thus be even more effective than a hard capping of lava in resisting erosion.



A SECTION THROUGH MOUNT RAINIER

A theoretical slice cut through Mount Rainier and the neighboring Cascade Range would show the inner construction of the volcano and the arrangement of the rocks that compose its base. The oldest rocks, the sandstone, shale, and coal beds of the Puget group (1), are exposed along the western foothills, and in the bottoms of some of the canyons. Later, these were covered by volcanic rocks of the lower Keechelus formation (2), and still later by upper Keechelus andesitic lavas (3). These earlier rocks were then cut through and invaded by magmas which upon cooling formed the Snoqualmie granodiorite (4). Following the uplift of the Cascade Range, erosion cut deeply into the Keechelus formation and the Puget group, revealing the granodiorite in places. The land surface, as it may have existed just before the Rainier Volcano, is shown by the heavy line (5). From deep magma chambers expanding gasses drove volcanic materials to the surface through cracks or tubes (6). Alternating deposits of ash, cinders, bombs, and pumice (7), and of andesite lava (8) piled up around the volcanic vent to form the cone of Mount Rainier. Since that time the cone has been deeply scoured, and the canyons somewhat deepened by glaciers.



MOUNT RAINIER AND EUNICE LAKE

ASAHEL CURTIS PHOTO COURTESY
WASHINGTON STATE HISTORICAL SOCIETY

MOUNT RAINIER
from PUGET SOUND . . .

Mount Rainier, lifting its icy summit 14,408 feet into the air, stands upon and covers nearly a hundred square miles of Washington's Cascade Mountains. These mountains so merge in the distant view that Mount Rainier seems to stand upon a high green-forested platform.

ASAHEL CURTIS PHOTO COURTESY
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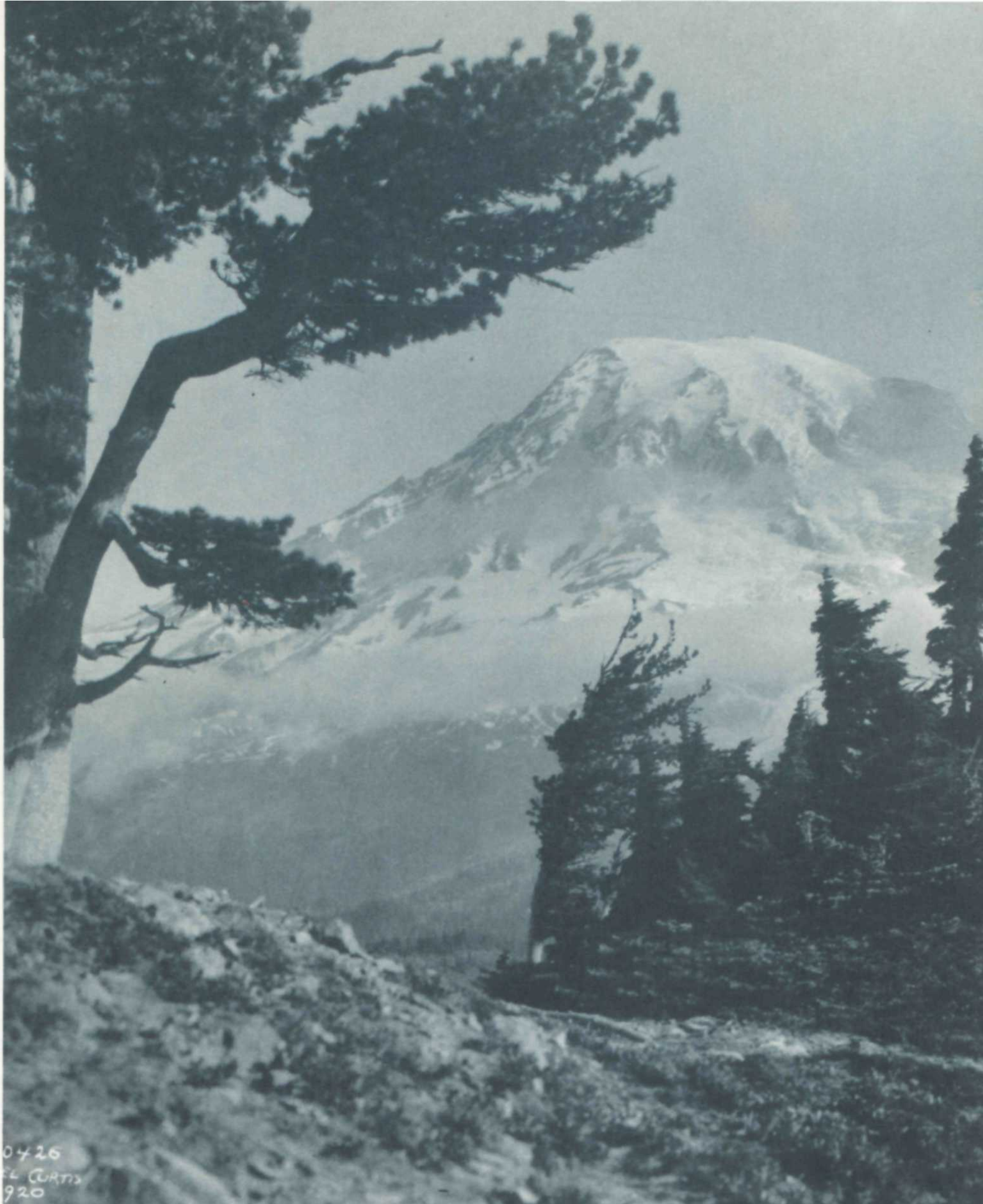


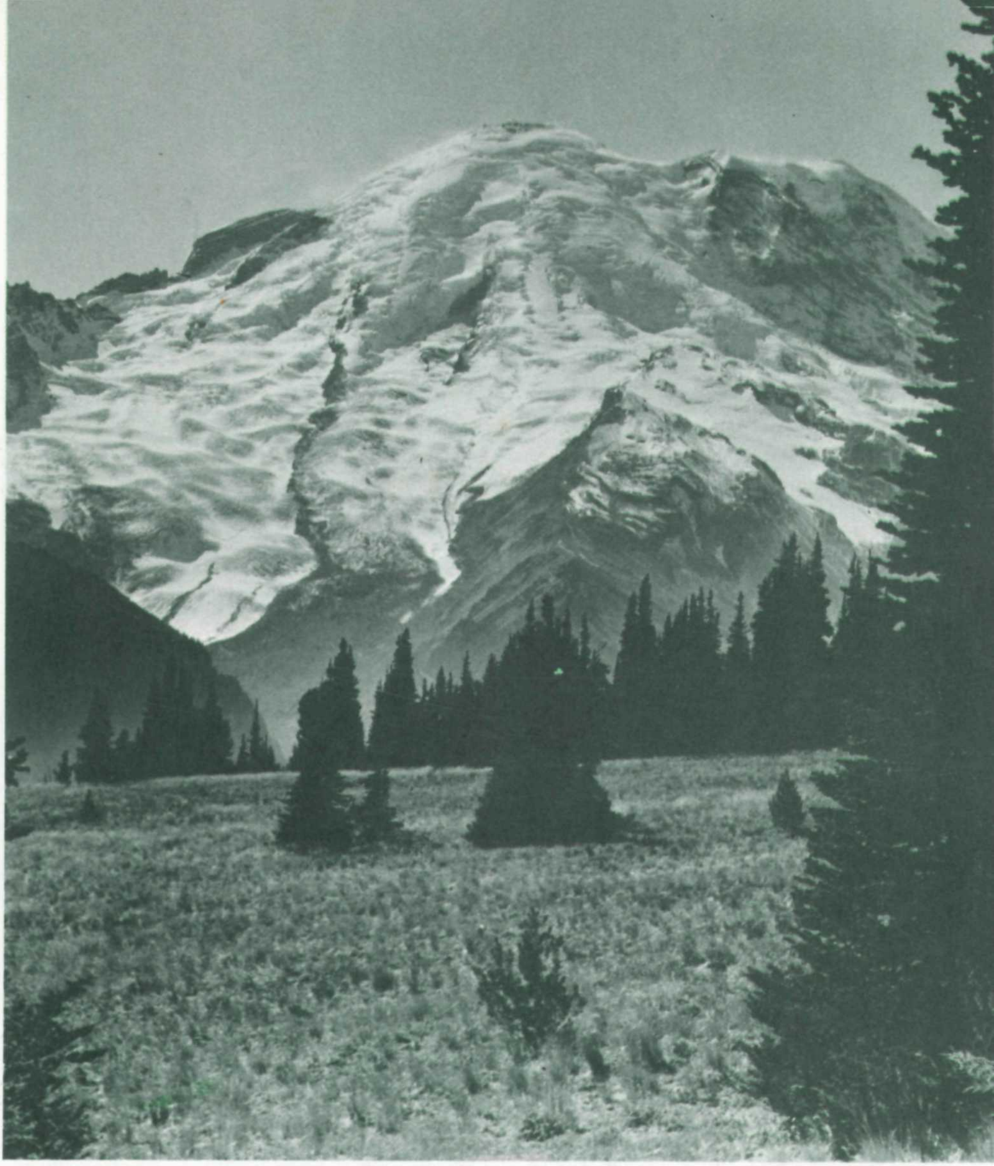
MOUNT RAINIER FROM THE TATOOSH RANGE

Seven miles away, The Mountain is revealed in its true perspective. Its glaciers and rocky ridges are clearly delineated, and it spreads its broad base to fill nearly one-fourth of the horizon.

ASAHEL CURTIS PHOTO COURTESY
WASHINGTON STATE HISTORICAL SOCIETY

COWLITZ PARK AND MOUNT RAINIER

The Mountain is domed and broad-shouldered. Its steeper sides are deep-cut by glaciers. Of its twenty-six glaciers, six begin in the ice fields of the summit, and creep downward within the canyons far below tree-line.



EMMONS GLACIER FROM YAKIMA PARK

Mountain parks cut by deep canyons and surmounted by individual mountain ranges compose the Cascade landscape around Mount Rainier's base. The parks are surprisingly flat or rolling areas forming benches and irregular table lands above the glacial canyons.

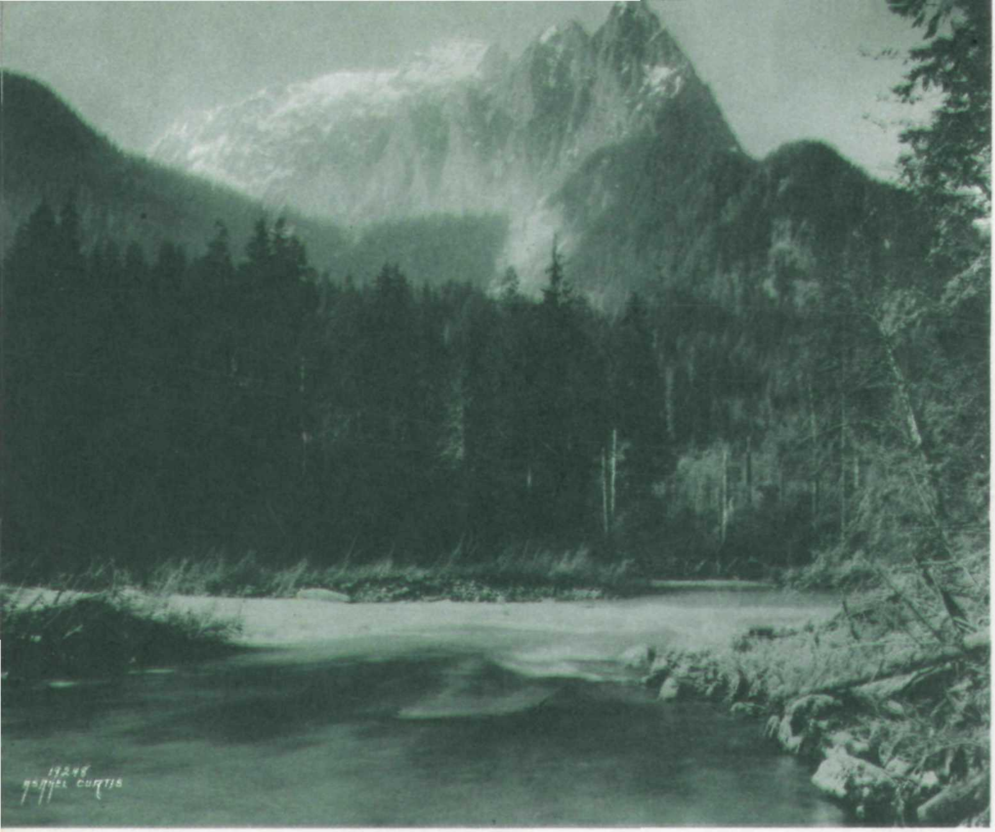
BASALTIC FALLS AND MUDDY FORK CANYON

Canyons of glacier and river are deeply entrenched below the parks and ridges. Smaller tributary streams, after flowing placidly over the parks, drop abruptly downward into the canyons.

PINNACLE PEAK AND THE CASTLE FROM PARADISE PARK

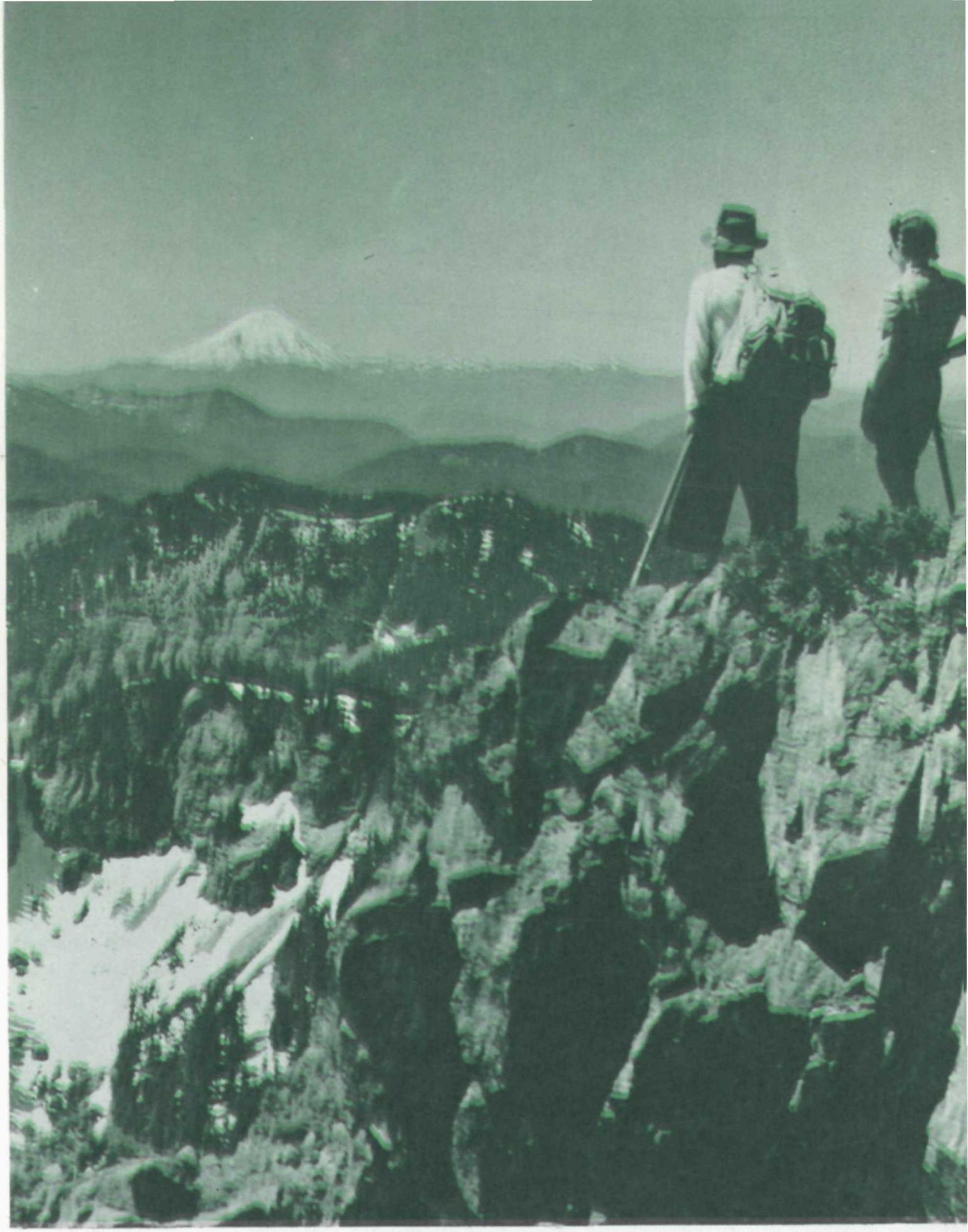
The sharp, abrupt peaks of the Cascade Ranges offer a pleasing contrast as they project as much as two thousand feet above the flattened parks.

RAINIER NATIONAL PARK COMPANY PHOTO



THE CASCADE RANGE—
INDEX PEAK . . .

The Cascade mountains were uplifted and carved into much their present form long before Mount Rainier grew to its present size. Volcanic rocks, not unlike the lavas of Mount Rainier, but considerably older, form the bulk of the Cascade.



MOUNT ST. HELENS FROM PLUMMER PEAK

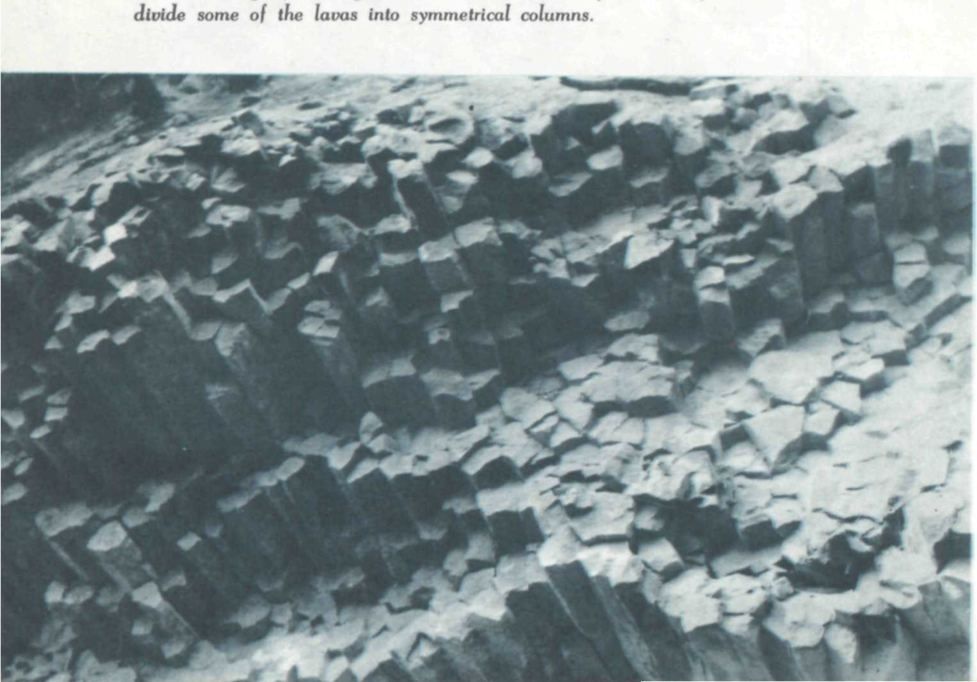
Cracks and fissures opened up along the Cascade Range, and spewed out lavas, ash, bombs, and pumice to build up the cones of the Cascade volcanoes —Mount Baker and Glacier Peak, Mount Rainier, Mount Adams and Mount St. Helens, Mount Hood, Mount Shasta, Lassen Peak, and many others. One of these, Mount Mazama, collapsed to form the caldera in which Crater Lake has formed.

LAVA AND GRANODIORITE CONTACT IN NISQUALLY CANYON

Some of the lava streams from Mount Rainier flowed for many miles down valleys in the Cascade Range. Later, the glacier canyons were cut deep enough to reveal, in places, the base of the lavas resting upon the older rocks of the Cascades.

COLUMNAR ANDESITE AT YAKIMA CREEK

The shrinking of cooling lava sheets caused the formation of cracks which divide some of the lavas into symmetrical columns.



LITTLE TAHOMA

Lava flows, alternating with deposits of ash, cinders, pumice, and breccias, now partly consolidated, formed in layers sloping away from the crater. Cross-sections through parts of the cone are today revealed in glacier-carved cliffs, and cayon walls.

NATT DODGE PHOTO

GRAND PARK . . .

Fine ash and frothy pumice, thrown explosively into the air, fell to blanket the surrounding landscape. The prevailing westerly winds carried most of this material to the northeast, and the deposits are several tens of feet thick at Yakima Park and Grand Park.

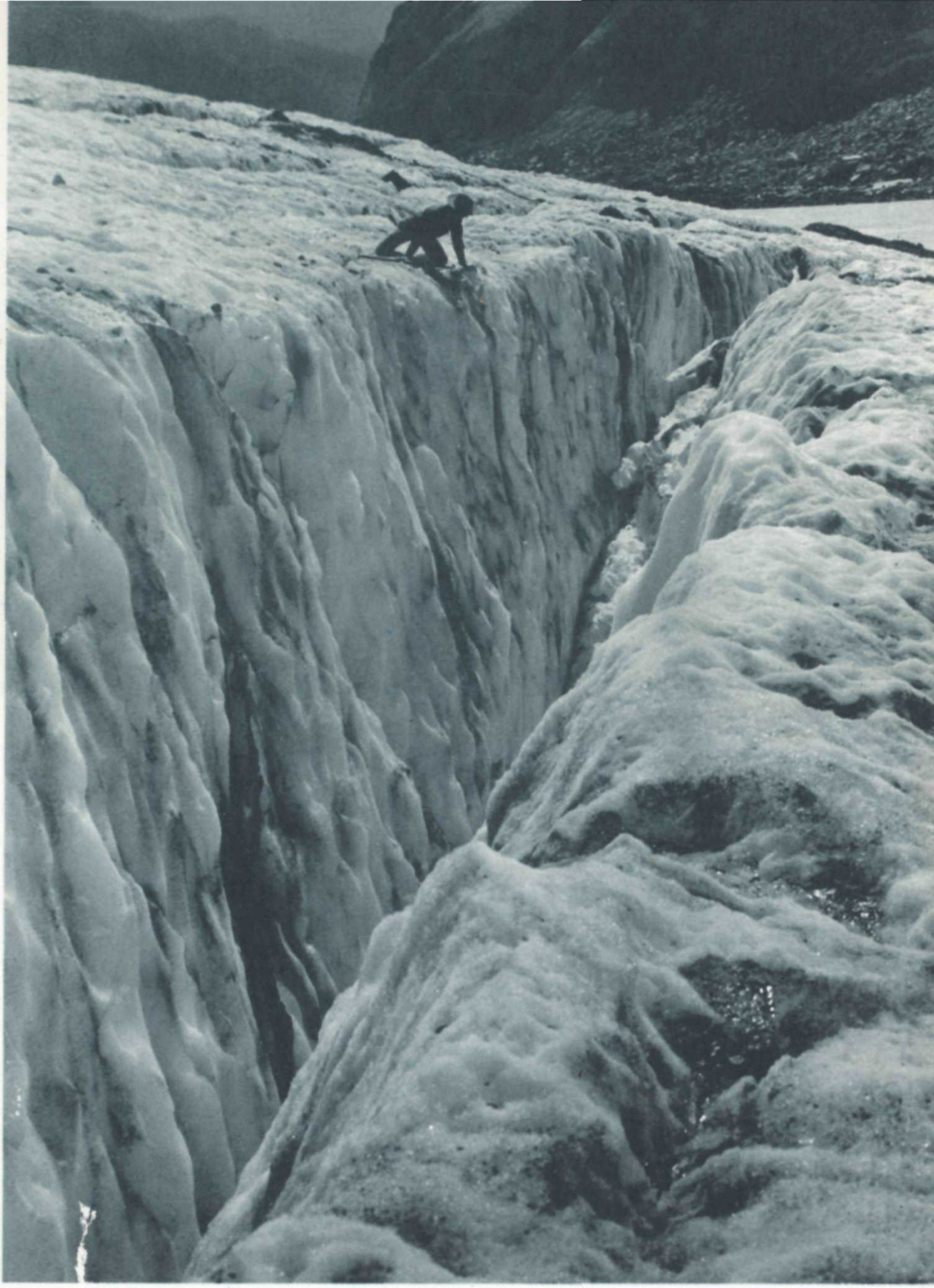
MOUNT RAINIER
from near IPSUT PASS . . .

The volcanic fires have cooled, and today Arctic cold holds sway. Twenty-six active glaciers course down the sides of the dormant volcano or form within huge amphitheaters sunk deeply into its flanks.

PARADISE PARK
IN WINTER . . .

Fifty feet of snow falls at mile-high Paradise Park, and it piles up to depths of fifteen to twenty feet. Higher up the mountain the summers are not long enough to melt all of the winter's snow. The residue, transformed into ice, feeds the glaciers.

FRANK BROCKMAN PHOTO



ON NISQUALLY GLACIER

When the ice becomes heavy enough, it begins to move and the glacier is born. Nisqually glacier, at an elevation of 7,000 feet, moves an average of 8 inches per day throughout the year. Deep crevasses form where movement is unequal.

CARBON GLACIER
and WILLIS WALL . . .

The moving ice quarries rock from the head and floor of the canyon. In this way it cuts back and downward into the mountain to form cirques. Carbon Glacier cirque, with 3500 foot Willis Wall at its head, is the largest on Mount Rainier. A dust cloud marks the almost continuous fall of avalanches.

THE WEST SIDE
from COLONNADE . . .

The compound cirques of South Mowich and Puyallup glaciers have cut deeply into the west side of Mount Rainier dividing the summit into three parts. Highest of these is the snow dome of Columbia Crest, with Liberty Cap to the left, and Point Success to the right.

OHANAPECOSH CANYON AND GLACIER AT INDIAN BAR

As it moves down the canyon, the rock-shod glacier scours its canyon deeper, and planes off the ends of projecting spurs and ridges. Glacier canyons thus become steep-walled, round-floored, and somewhat straighter than before.

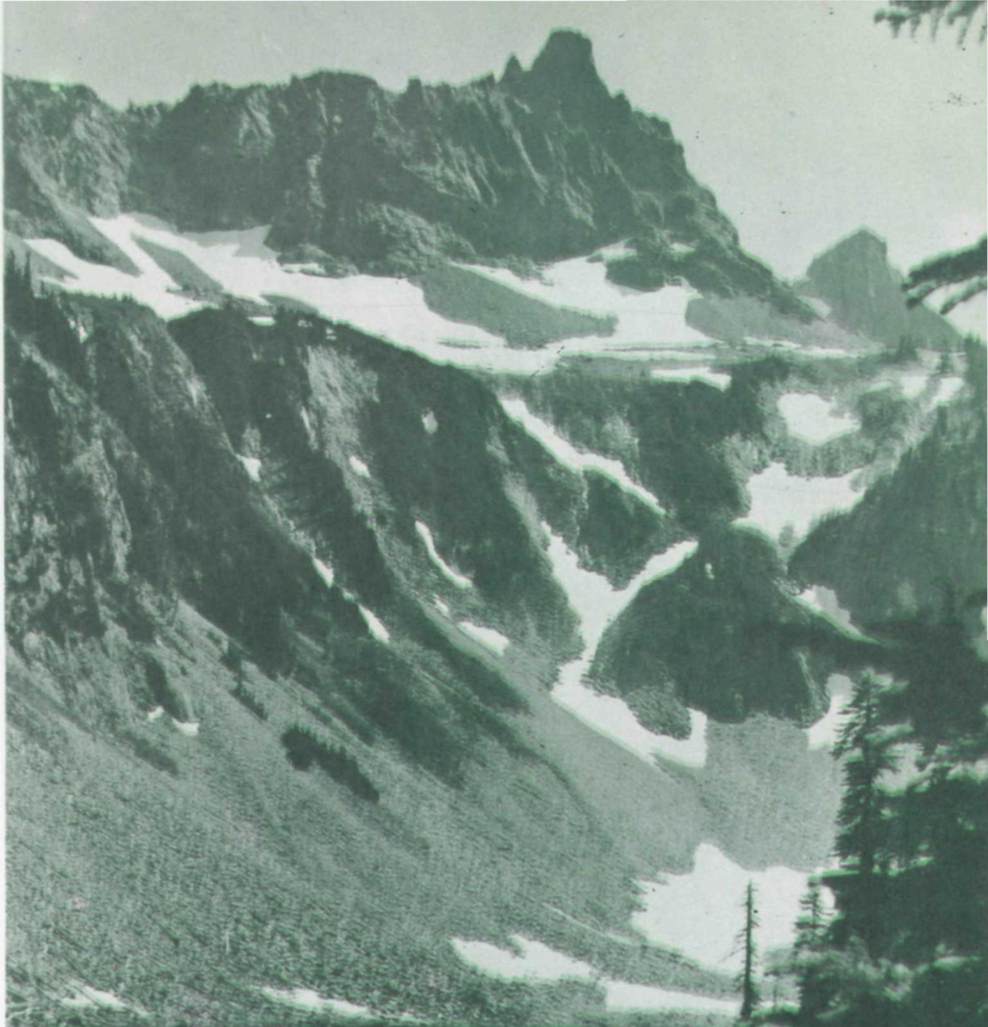
FRANK BROCKMAN PHOTO

TERMINUS
of CARBON GLACIER . . .

The glacier acquires a heavy load of rock through its own erosive action, and from avalanches from the canyon walls. Riding upon and within the ice, this rock debris is transported to the terminus. Melting of the ice plunges this material to the canyon floor where it accumulates in uneven, irregular piles.

THE WEDGE-EMMONS
and WINTHROP GLACIERS
from BURROUGHS MOUNTAIN . . .

As the large glaciers sink themselves into the mountain, rock wedges, and rib-like cleavers are left exposed between them. The Wedge, with Inter-glacier on its face, splits the upper ice stream into the Emmons Glacier on the left, and Winthrop Glacier on the right.



UNICORN PEAK AND SNOW LAKE

Glaciers, cutting their cirques headward, often bevel several sides of a lone-standing peak, or cut back from both sides into a mountain ridge. In this way the summits are reduced to sharpened peaks and serrate ridges. Lakes often form in the cirque basins after the ice has melted.

MIRROR LAKE

Many small lakes and pools collect in the depressions behind the uneven piles of glacial moraine on the mountain parks.

COMET FALLS

The higher waterfalls of Mount Rainier National Parks have formed where a tributary stream plunges from a high park level, or from the mouth of a shallower glacial valley, into an over-deepened glacial canyon.

NATURAL BRIDGE AND LAKE ETHEL

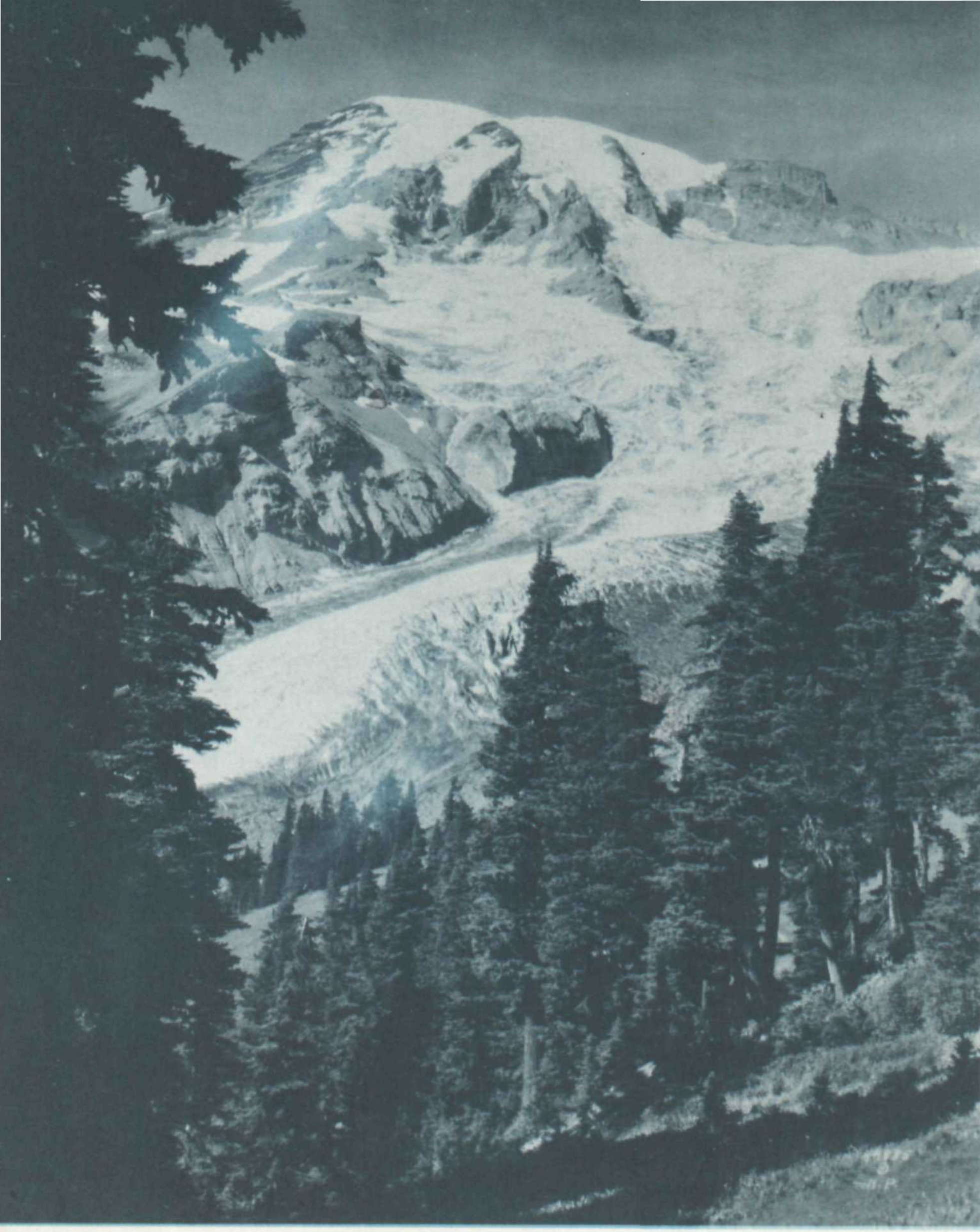
Mount Rainier's glaciers were once many miles longer than they are today. Once the parks and Cascade mountains also were covered with glacial ice. All of the lakes of this area, even though today they may be crowded by the dark forest, were of glacial origin.

NISQUALLY GLACIER TERMINUS, 1915

The melting back of Nisqually Glacier is noticeable from one year to the next, and has been witnessed for over fifty years. The thick, bulging prism of ice which reached within 1500 feet of Glacier Bridge in 1915 had become in 1944 a thin, channeled nearly buried ice tongue, about 3500 feet above the bridge.

ASAHEL CURTIS PHOTO COURTESY
WASHINGTON STATE HISTORICAL SOCIETY

NISQUALLY GLACIER TERMINUS, 1944



NISQUALLY GLACIER, 1923

While the terminus is melting back, the lower part of the glacier also becomes thinner. Twenty-one years' wastage of the lower Nisqually Glacier has exposed the rock dome over which the glacier once cascaded. The stream of clear ice has melted far down to leave prominent ridges of moraine-covered ice along the borders. While many snowfields and ice fields have disappeared, the higher portions of the glacier proper shows but minor changes in this period.

ASAHEL CURTIS PHOTO COURTESY
WASHINGTON STATE HISTORICAL SOCIETY

NISQUALLY GLACIER, 1944

BOX CANYON, MUDDY FORK OF COWLITZ RIVER

Rivers issue full-born from beneath the glaciers. Heavily laden with rock debris, they follow a devious course through the moraine-strewn valley below the glaciers. Where the gradient is steep, they clean away some of the moraine, then cut new trenches deep below the older glacial valley floor.

ASAHEL CURTIS PHOTO COURTESY
WASHINGTON STATE HISTORICAL SOCIETY

AT TREELINE BELOW PARADISE GLACIER

The slow creep of plants has followed the retreating glaciers from the very shores of Puget Sound. At tree line, and below the terminus of the glaciers, we observe today the same orderly advance of vegetation to clothe The Mountain.

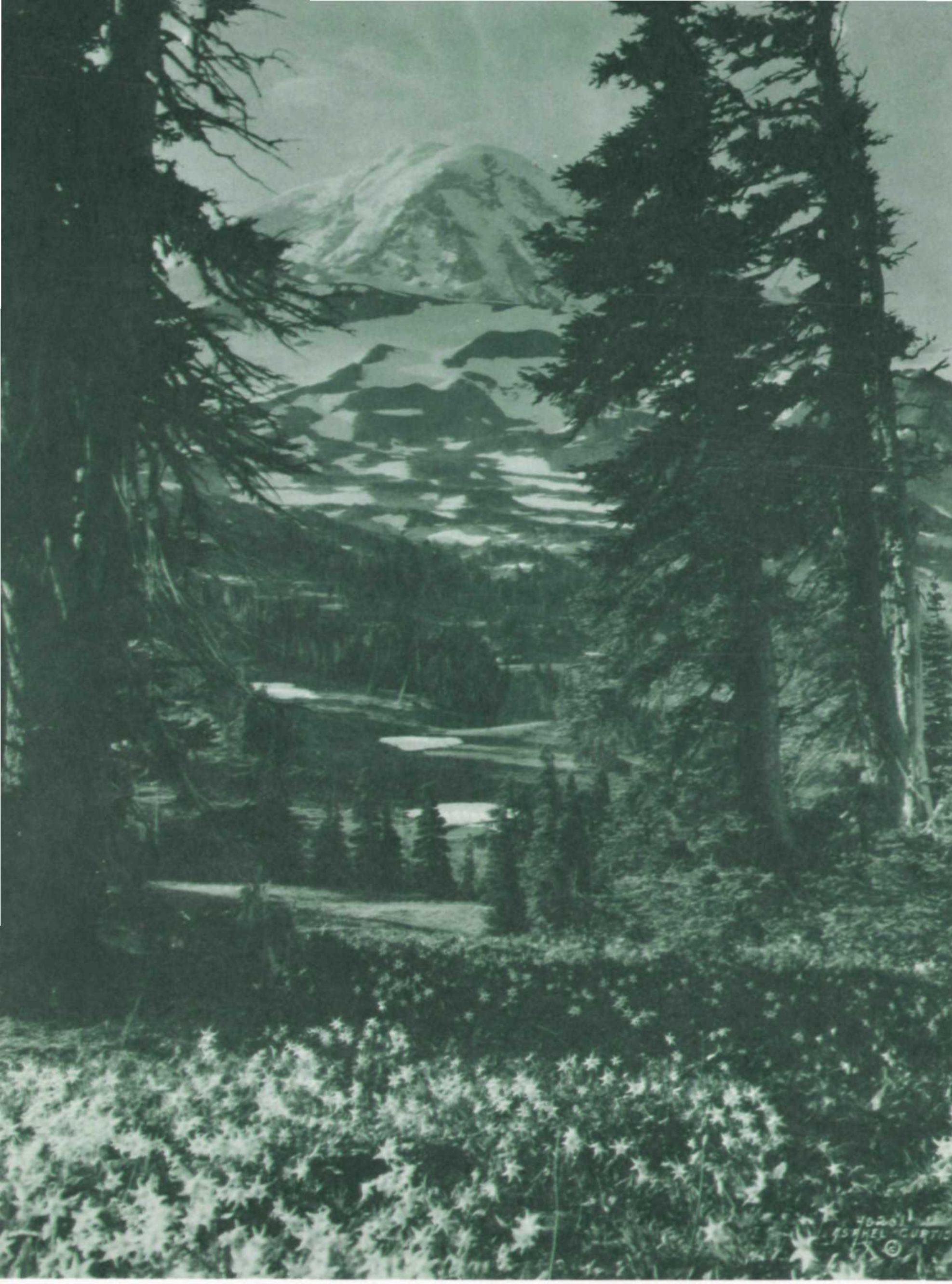
TERMINUS OF EMMONS GLACIER

LOGGING AREA
ALONG MOWICH RIVER . . .

Man, himself, is a geologic agent. He bends Nature's forces and her resources to his own needs, often effecting great changes in a landscape. He, thus, must satisfy certain of his physical needs.

EUNICE LAKE
and MOUNT RAINIER . . .

A few peerless compositions of the Master Artist, comprising less than one percent of this Nation's lands, have been reserved as National Parks. These will remain forever unspoiled, dedicated to the service of man's spirit through recreation and inspiration. As they contribute to a balanced life, these lands yield their highest reward to the Nation and its people.



THE SPRAY PARK COUNTRY

ASAHEL CURTIS PHOTO COURTESY
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CHAPTER III

The Volcano . . .

The Pliocene period was one of mountain building throughout the world, and especially on the continental borders of the Pacific Ocean. Likewise, the late Pliocene and Pleistocene periods witnessed the birth of many great volcanoes in these same areas. The location of active mountain building and of active volcanoes within the same narrow zones easily leads to an assumption that there must be a causal relationship between these two dynamic processes. Crustal movements may not be the ultimate cause of volcanism, but fracturing, folding, and uplifting of the mountains may, at least, be the final event, the "trigger," which sets off volcanic activity.

The rocks deep within the earth are hot and are kept so by heat from deeper sources. Generally speaking, with each 100 feet of depth, rock temperatures rise about 1 degree centigrade. While this rate of increase is not constant, nevertheless, the rocks 40 or 50 miles below the surface are thought to be sufficiently hot to melt except for one factor, they are firmly confined beneath the tremendous weight of the overlying rocks. They cannot undergo the expansion required in the change from solid to liquid form. Pressure normally keeps these super-heated rocks rigid. When mountains are uplifted, however, this pressure may be reduced locally sufficiently to permit the rocks to liquify. Also, the cracks, faults, and folds, formed during the mountain uplifts, may create weak zones along which the newly formed magmas move toward the surface. Motive power is provided by the weight of overlying rocks, and the pressure of gases released from the newly formed magmas. The melting and dissolving action of these hot and chemically active magmas assists in the surfaceward movement of the molten rock.

The first eruption of Mount Rainier was not an isolated nor unique event. Rainier was but one unit of a great system of volcanoes surrounding the Pacific Ocean. Starting in the Andes of South America, we can trace this volcanic chain northward through Central and North America, westward through the Kurile Islands, Japan, and the Philippines, to New Zealand. Most of the islands of the South Pacific are either volcanic, or contain within their mountain ranges many volcanoes. Within the United States, only Lassen Peak in northern California has been in active eruption within historic time, but eruptions of ash, dust clouds, and steam, were reported from Mount Baker and St. Helens in 1842. In Central America, Alaska, Kamchatka, Japan and in the South Pacific and East Indies, many volcanoes are still active today. Paricutin, the volcano which began in a Mexican cornfield in 1943, may be considered a recent member of this volcanic family. Mount Baker, Glacier Peak, Mount Rainier, Mount Adams and Mount St. Helens in Washington; Mount Hood, Mount Jefferson, and Mount Mazama, which subsided to form the caldera of Crater Lake in Oregon; and Mount Shasta and Lassen Peak in northern California are the major Cascade volcanoes of this world-wide group.

When did Rainier first begin to erupt? There is no definite indication of the exact time. Some of the volcanoes of the Cascades probably had their origin in late Pliocene time, perhaps as much as two million years ago. Judging from its great size, Rainier may have been one of the earlier volcanoes. Not all were in eruption at once. Some blazed on the horizon for a few thousand years, perhaps, then died out as neighboring vents erupted in their place. As a group, however, these volcanoes have continued from the late Pliocene to modern times. Rainier is reported to have had feeble eruptions of dust in 1853, 1854, 1858 and 1870. The glacier system, and the degree of dissection of The Mountain of today, however, surely indicate that it has been many hundreds or thousands of years since Rainier experienced a major eruption.

The first activity of Rainier was probably the escape of gasses from newly opened cracks and fissures in the earth, followed by eruptions of ash and pumice. The uprushing gases and rock cleaned and widened the volcanic vent. Pumice, ash, cinders, bombs, and broken fragments of lava and bedrock were thrown into the air, and fell around the orifice of the volcano to start the building of the cone. The process was accompanied by sharp, loud rumbling within the earth, and a cadence of reports like the rolling of thunder attended the eruptions. Immeasurable volumes of steam together with pungent hydrochloric acid and sulphurous gasses preceded and accompanied each eruption. Great cauliflower clouds of these gasses and of the finer dust-like particles of volcanic ash formed over the vents, and rose thousands of feet into the air before being dissipated by the winds. Lightning flashed within these clouds, and upon condensation, the water rained down torrentially upon the surrounding landscape.

At other times liquid, fluid lavas welled upward in the volcanic pipes, filled the crater to overflowing, spilled downward over the pumice and ash slopes of the cone, and flowed out into the valleys of the neighboring Cascades. Some of these flows continued for as much as 10 miles before being slowed to a halt by cooling and solidification. As more and more fragmental material piled up to build the cone still higher, the lavas no longer found it easy to rise to the crater, but sometimes broke through the flanks of the mountain.

Sometimes the volcano rested, with only scattered fumaroles, steam vents and hot springs active in dissipating the pressures and heat from below. At other times the crater filled with fiery, seething lavas, a lake of molten rock kept hot by the bubbling of superheated gasses from below. Fragments of liquid, viscous lava shot into the air, the smaller blobs solidifying at once, the larger masses falling as steaming, pasty chunks, to spatter upon the crater rim.

At times when the interior pressures of the volcano were fully released, the in-falling lava fragments, and the solidifying lavas, choked and sealed the vents, and the volcano rested. When the gasses were effervesced from the magmas developed sufficient pressure they broke through this volcanic plug, throwing out with explosive violence the fragments of the "cork," and a new period of eruption followed.

There were long periods of quiet between some of the eruptions. This is indicated by the occurrence of glacial deposits beneath and between some of the lava flows. These features suggest that glaciers may have formed even before Rainier came into being, and certainly they must have formed at times during the intervals between eruptions.

The relation of various flows of lava to the underlying topography further demonstrates that this volcano was intermittently active over a very long period of time. The early flows followed the existing valleys in the Cascades. Then new valleys were carved by rivers and glaciers. The new valleys often followed the margins of earlier flows, leaving the lava-filled former valleys standing as interstream ridges. This appears to have been the case with The Ramparts, and with Stevens Ridge. The Stevens Ridge flow was followed by two others. The first of these flooded southeastward against the Tatoosh Range and around its eastern end. Today, the surface of this flow forms The Bench. Again streams cut downward through this second flow, deepening Stevens Canyon much as it is today. The last flow plunged and cascaded downward into the upper end of this canyon. Thus, the periods between successive lava flows were sufficiently long to permit the erosion and deepening of some of Rainier's canyons.

During the later stages of activity, the eruption of fine volcanic ash and frothy pumice predominated. The larger fragments accumulated around the crater on the upper slopes of the cone, but the finer materials were blown by the prevailing winds, largely to the northeast. Deposits of ash and pumice thus cover many of the park-like areas north and east of Mount Rainier. Yakima Park and Grand Park are the most spectacular examples of these deposits, but the yellowish ash layers may be seen as well in most of the sub-alpine parks and ridges wherever the soil has been broken through to expose them. In some places as many as three or more thin ash layers, alternating with black soil layers, drape themselves like blankets over the present topography. The intervals between ash showers were sufficiently long to permit the development of black soil; and green vegetation crept up the volcanic slopes several times only to be destroyed by later falls of ash.

In many places today the lava sheets exhibit a very regular system of joints or cracks as if made up of exact-fitting 5, 6, or 7 sided columns. These columnar blocks were formed as the sheets of lava contracted upon cooling. The shrinking stresses were compensated for by the development of cracks intersecting at about 120 degrees. This is the minimum arrangement to give relief to shrinkage in all horizontal directions. Further cooling extended these cracks until they intersected others radiating from adjacent centers of shrinkage, completing the outline of the columns. The columns are arranged perpendicular to the top or base of the lava sheets.

CHAPTER IV

The Glaciers . . .

Except for the small steam vents within the summit crater, and some warm mineral springs, there is little today to suggest the intense volcanic heat of the past. Arctic cold has taken over; the peak today bears upon its slopes the most extensive glacier system in the United States. Twenty-six glaciers, among them the Emmons, largest glacier in the United States, have their origin in the summit ice cap or in glacier-carved basins around the upper flanks of Mount Rainier.

THE ORIGIN OF THE GLACIERS

Glaciers are spectacular geologic agents, but there is nothing particularly mysterious in their origin. True, Mount Rainier does not have an exceptionally cold climate. In fact, compared with interior mountains such as the Rocky Mountains, temperatures are comparatively mild. Yet, the Nation's largest glacier system radiates outward from Rainier's cone. Rainier does have an abundant snowfall, and glaciers form wherever and whenever, over a sufficiently long period of years, the winter snowfall exceeds the quantity melted during the summer. Even today, the hot summers are not long enough to melt all the snow of the preceding winters. The normal precipitation at Paradise is about 100 inches per year, and most of this falls as snow. As much as 50 feet of snow may fall in a season, accumulating to depths of from 15 to 25 feet.

Why this heavy snowfall? The explanation lies in part in the nearness of the Pacific Ocean, and in part in the location of the Cascade mountain barrier, a short distance inland. The Pacific Ocean and its arm, Puget Sound, breathe tons of water into the atmosphere each day. The prevailing west winds sweep this inland across the lowlands and mountains where it falls as rain and snow. This precipitation is brought about by the cooling of the air as it crosses over colder land during the winter, but, of more importance in the mountains, it is caused by the chilling of the air as it lifts upward over the highlands. Thus, not even the weather, nor the flowers and trees that depend upon the rains, nor the modern glaciers, can be considered without reference to the geologic events of the past which raised the Cascade Mountains.

During the glacial period either because of heavier snowfall, or cooler summer temperatures, or both, there was a greater carry-over of snow each season, than in modern times. This unmelted snow gradually lost its snowy texture, and became compacted into solid ice. When the accumulating ice became heavy enough, it began to move slowly downward under the pull of gravity. With the beginning of movement, the glaciers were born.

Much remains to be learned of the actual mechanics of glacier movement, but that they do move has been demonstrated many times. The most recent measurements of the movement of Nisqually Glacier were made in 1944 and 1945. Steel rods were driven into the ice in a straight line across this glacier at an elevation of about 6800 feet. Then, periodically, the movement of these rods downward from the original line was measured. In the course of a full year, the displacement near mid glacier totaled nearly 250 feet, an average of 8 inches per day. Movement is slightly faster during the summer (8.9 inches per day) than during the winter, and most rapid near the middle of the glacier.

Any differential movement in the glacier results in the formation of cracks and crevasses. The tension developed in the brittle ice where the glacier passes over irregularities in the canyon floor may produce a very intricate system of intersecting crevasses. Others are caused by the faster movement of the center pulling away from the sides of the glacier. These crevasses may angle upstream from the borders, or run the full width of the glacier. Sometimes crevasses parallel to the borders are found where a widening of the canyon, or where melting along the edges permits the glacier to spread. Crevasses are not permanent features, but may open and close as the ice moves. Crevasses offer the greatest hazard to mountaineering, particularly when concealed beneath new snow.

In an active, expanding glacier, the entire prism of ice moves, but in glaciers which are melting rapidly, and whose lower portions are becoming thin, the rate of movement slows with progression down stream. Nisqually Glacier at its terminus moves at the most not over a few feet per year.

GLACIER SCULPTURING

It is through its movement that glaciers, of all agents of erosion, produce the most spectacular sculpturing effects on high mountains. The faceted peaks, cliffs, broad, flat-floored amphitheaters, deep, steep-walled canyons, as well as nearly all the lakes and waterfalls of such areas as Mount Rainier National Park, Sequoia National Park, and Grand Teton National Park, owe their form or existence to glaciers. It is largely the movement of the ice that enables the glacier to produce its manifold sculpturing effects.

Glaciers erode their valleys in two ways: They quarry, and they grind. Quarrying action is particularly active at the glacier head. Beneath the glacier the ice may freeze to or around loose boulders. Freezing water in cracks may wedge out large fragments from the bed rock. The ice itself, under the pressure of its own weight, may squeeze into cracks in the rock. Rock materials thus becomes embodied in the glacier. Then as the ice moves, such rock is plucked from place and carried on with the ice. In this manner glaciers quarry an ever expanding amphitheater or cirque back into the mountain. The deepest on Mount Rainier is the cirque of Carbon Glacier cut nearly 3500 feet below Liberty Cap. Sunset Amphitheater is the cirque of Puyallup Glacier, but the best defined cirque is that of Cowlitz Glacier, outlined by Cathedral Rocks, Gibralter Rock, and Cowlitz Cleaver.

The plucking action operates as well in the lower course of the glacier. Where the bed rock is relatively soft or shattered, local basins are quarried out giving the glacier canyon a giant stairstep profile. This is particularly well displayed by Nisqually and Winthrop Glaciers.

Clear, clean ice is not effective in abrasion, but glacier ice is not clean, for all the quarried rock is held frozen in its base. Pressed downward by the tremendous weight of the glacier, these rock "tools" scour into bed rock as the glacier moves. The canyon is deepened and widened. It is straightened by the planing off of projecting rock spurs. As a result, glacial canyons become steep walled, and round to flat floored. They sweep down through the mountains in long, regular curves.

Rainier glaciers are also agents of transportation and are constantly engaged in moving rock material downward from the mountain. The glaciers, through their erosive action, provide part of the rock load. As the glaciers sink themselves deeper into the mountain, still more material is supplied by rock falls and avalanches from above. By the time the ice has moved to the melting terminus it carries a heavy burden, frequently sufficient to completely cover the ice. The melting ice dumps this material in irregular piles upon the canyon floor to form the moraine. Distinct ridge-like terminal moraines are not evident around the melting ends of Rainier's glaciers, for recession is so rapid that each season's morainal deposit is made well upstream from that of the preceding year. Lateral moraines, along the melting borders of the ice, and medial moraines, which form where two branches of a glacier come together and merge their lateral moraines, are conspicuous on many glaciers of Mount Rainier.

Once Rainier was a smooth-contoured cone, similar, but for its truncated summit, to Mount St. Helens. Today it is rugged and deeply trenched with glacier canyons and cirques. So deep cut are some of the gouged cirques and canyons, that thousand-foot masses of rock which were formerly a part of an even mountain slope, stand out from the sides of the mountain. Little Tahoma, and Gibralter Rock thus have been isolated from The Mountain proper by the carving of the cirques and canyons of the Nisqually, Ingraham, and Emmons Glaciers. Similar in origin are the wedges and cleavers which today separate the close-spaced ice sheets arranged around the summit, into diverging glacier streams. Steamboat Prow, separating the Emmons from the Winthrop Glacier; Colonnade ridge between South Mowich and Puyallup Glaciers; Puyallup Cleaver; Success Cleaver, and the Wapowety Cleaver are all conspicuous examples.

Once we have seen what the glaciers are still doing to The Mountain, the many glacial features of the surrounding Cascade Range become obvious. The north face of Pinnacle Peak has all the markings of the headwall of a glacial cirque. In fact, the last relict ice of Pinnacle Glacier, nearly buried beneath talus, still floors a part of the basin at the foot of this cliff. Other glaciers once cut into this peak from the northwest and from the south, and the beveling action of all three has reduced what was once a more massive, rounded mountain into a sharp faceted peak. Similarly, the peaks of Mother Mountains, Governor's Ridge, the Sluiskin Mountains, and other Cascade ranges have been sharpened by glacial sapping from two or more sides. Quite in contrast to its general effect upon the canyon, glacier erosion renders more rugged and serrate the summit peaks and ridges.

Often glaciers excavate the cirque head deeper than the point of discharge of ice from the cirque. When the ice disappears, water collects in these depressions to form lakes. Mowich Lake, Snow Lake, Lake George and Lake Crescent are fine examples. Most of the larger lakes of Mount Rainier are either in cirques, or in the down-valley depressions of a glacial stairstep. The smaller lakes, like Mirror Lake and the many other small pools and ponds on the mountain parks, have formed in depressions behind or upon old moraine deposits. All of the lakes of the park owe their origin to the glacial experience of the past.

Most of the waterfalls, too, were caused by glaciers. Some falls, such as Carter Falls or Sluiskin Falls on Paradise River, have formed where the stream plunges from one glacial cirque or stairstep to the next lower. Most of the higher falls, however, are on smaller tributary streams, and form where such streams drop from mountain parks into the overdeepened glacial canyons. Basaltic Falls and Pearl Falls are two outstanding examples. Still others have formed where a major canyon, with its larger, more powerful glacier, was deepened below the level of its tributary. Comet Falls and Christine Falls illustrate this type. The deepening of the main canyon left the smaller tributaries literally "hanging" high up the canyon walls.

GLACIER RECESSION

There are no active glaciers today in the Cascade mountains surrounding Mount Rainier. Yet these lesser peaks and canyons bear the unmistakable profiles of glacial sculpturing. Rainier's long, U-shaped canyons, the hummocky morainal topography of mountain parks, moraines deep in the valleys so old they are covered by dense forests—these are additional evidence that once glacial ice blanketed most of the mountains and pushed down the canyons to the foothills of the Cascades. The ice has long since melted from the lower mountains, and has shrunk far back to Rainier's lower slopes. This recession continues, and has been under exact observation for some 30 years. Since 1919, annual measurements of the Nisqually Glacier have been made, and in more recent years several of the other major glaciers have been similarly observed. All show a considerable variation in the position of the terminus from year to year, but all are melting back. The Nisqually, for example, recedes at an average rate of about 70 feet per year. In 1903, this glacier extended to within a few feet of the location of the present glacier bridge. Today it is nearly three-quarters of a mile upstream. The Paradise-Stevens Glacier, too, has had an interesting recession. Of smaller size, moving more slowly to replenish melted ice, and located on an exposed, south-facing slope where the warming influence of a hot summer sun is most effective, this glacier has melted back from a position only a few hundred feet above Sluskin Falls to its present position within 50 years. Stevens Glacier, formerly a small tongue diverting part of the ice toward Stevens Canyon, has disappeared.

Thinning of the lower portion of a glacier accompanies the recession of the terminus, as is easily seen by comparison of old and modern photos of the Nisqually Glacier. This thinning is responsible for some rather interesting effects. When a glacier is vigorous and in active movement throughout its entire length, it is able to maintain a bulging profile-thickest in the middle, thinner toward the margins. The ice in mid valley also may push a considerable distance downstream beyond the borders. Most of the rock material is retained along the glaciers' borders, leaving the center ice comparatively clean down to the extreme terminus.

As thinning progresses, movement becomes slower, and when the ice is reduced to from 100 to 150 feet in thickness, motion practically stops. Then the faster melting along the center line of the glacier results in the formation of well defined valley on the surface of the ice. The central portion of the terminus melts back until it forms a deep, horseshoe-shaped reentrant.

With the thinning of the ice, the unstable canyon walls are left unsupported, and there follows an ever increasing fall of rock material on tp the glacier. With the deepening of the mid-glacier valley, the migration of this rock material progresses until the entire glacier becomes competely covered. This covering, however, serves to insulate the ice against the sun rays, and we can be sure that recession of Rainier's glaciers has been decidedly retarded by this protective coating.

Small, restricted glaciers, especially those on exposed slopes, may completely disappear under present climatic conditions. The canyon glaciers, however, those deeply entrenched into the mountain, with large catchment basins at elevations providing abundant snow, will doubtless persist indefinitely. True, they are melting back, and their lower portions are becoming thinner. This merely is a manifestation of the fact that the glacier lags considerably behind the climatic changes which determine its growth or recession. A cooler climate and increased snowfall must continue many years before being reflected in a noticeable change in a glacier. Likewise, warmer climate and decreased snowfall may not reveal its total effect on the glacier for many years. There is some indication that the large glaciers, those fed from summit snow fields and mid-elevation cirques, under present climatic conditions will become stabilized at elevation of around 6000 feet. Snow left above this level each year just about balances the ice lost by downward movement and melting.

CHAPTER V

Glacial Aftermath . . .

THE RIVERS

There are rivers of water beneath the rivers of ice. All of the melt water from the glacier surface soon finds its way downward through crevasses and wells to the valley floor. At the glacier terminus, full grown rivers emerge, heavily laden with rock flour, sand, and gravel, the products of glacier grinding.

For some distance below the glacier, the river follows a difficult, devious course among and over the irregular deposits of moraine. For most of its course to the sea, it is completely engaged in the task of moving these products of glacier erosion. The glacier flour, sand, and gravel, it carries away at once, and it is frequently so heavily laden with these that the waters are discolored a chocolate brown. The larger boulders it leaves for flood time, then jumps them along the stream bed. The pounding and knocking of these boulders together at such times is audible for a half mile or more from the river. The larger glacial boulders are rolled, undermined, and so pushed on down the river; and the largest ones the river eventually wears down to more convenient size.

In general the river attempts to smooth out its course. It may fill lakes with sediment, or drain them by cutting down the outlet. Falls become cascades, and cascades are reduced to smooth flowing channels by the downward cutting of the river. A vivid example of post-glacial stream erosion is the Box Canyon of Muddy Fork. Here, what was apparently a rock dome of a glacial valley floor, has been cut to form an extremely narrow, vertical-walled trench over 100 feet deep. Thus the rivers, active before the glaciers were formed, remain to carry on the work after the ice has retreated.

CLOTHING THE MOUNTAIN

The creation of the modern landscape was not completed with the dying of the volcano, nor with the recession of the glaciers. The volcano left this area a desolate, bleak expanse of grey ash and pumice, and drab lavas. Then, for a time, glacial cold barred the advance of meadow and forest. Today the upper half of the Mountain and the ice tongues that push far below the normal timberline still resist the advance of vegetation. Certainly, the struggle which produced the deep forests and the colorful flower meadows which we enjoy today has been long and difficult. No eye-witness can tell us the details of the slow advance of plants, and of their orderly succession as they reclaimed the glacial canyons, the ash-strewn parks, and the lava ridges. But, in following downward from the barren wastes above timberline, we may today witness the parade of plants in the order in which they must have followed each other from the very shores of Puget Sound to the limit of vegetation which we now observe.

Above timberline the lichens are the first to secure anchorage on the rocks. These produce the first soil as their waste products decompose the rock. In protected cracks and moist hollows, mosses continue the process. Certain grasses, and plants like the Lyall lupine, mountain eriogonum, and wooly pussytoes may gain a foothold in the loose ash and pumice soil. But, still, most of the ground is barren, and there is little to bind the loose soil materials in place. This task is assumed, a little farther down the mountain, by the thick matting of mountain-heath, blueberry, and grasses. Then follows the entire host of plants of the mountain meadow—flowering plants of brilliant hue, grasses, rushes, and shrubs—so closely crowded that they form a protective blanket over entire hillsides and meadows. Windblown whitebark pine of timberline gives way to artistic family groups of alpine fir and hemlock on the mountain meadows. These pass downward into thickets of mountain ash and azalea, and in turn are succeeded by thickening forests of the canyons.

A similar progression of plants follows the retreat of such glaciers as the Nisqually, Tahoma, or Emmons, but here the entire succession from barren rock at the melting edge of the glacier to thick forest may be compressed within a distance of a half mile. On the canyon walls, the complete series often is still more compressed and the stages of revegetation clearly mark the successive stages in glacier recession.

An avalanche lily, growing in an alpine meadow recently bared by melting snow, is an object of exquisite beauty, delicate of form and clear of color. It is an entity unto itself, and as such may be intensely enjoyed. But, it is more than just a flower. It may be considered as a symbol, carrying meanings which project far back in geologic time. It symbolizes the earth movements that lifted its environment high into an elevation of near arctic climate, high enough to intercept snow and rain from the westerly winds. It recalls volcanic eruptions, for the nourishing soil in which it grows was once volcanic lava and ash. Rivers and glaciers have prepared its bed, and it feeds in part on the remains of plant pioneers. A flower is more than a mere blossom, a waterfall is more than a stream out of adjustment, and a mountain peak is more than just a pile of rocks. No one can observe completely one single object of Nature without becoming aware of the entire landscape and the whole of geologic time.

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