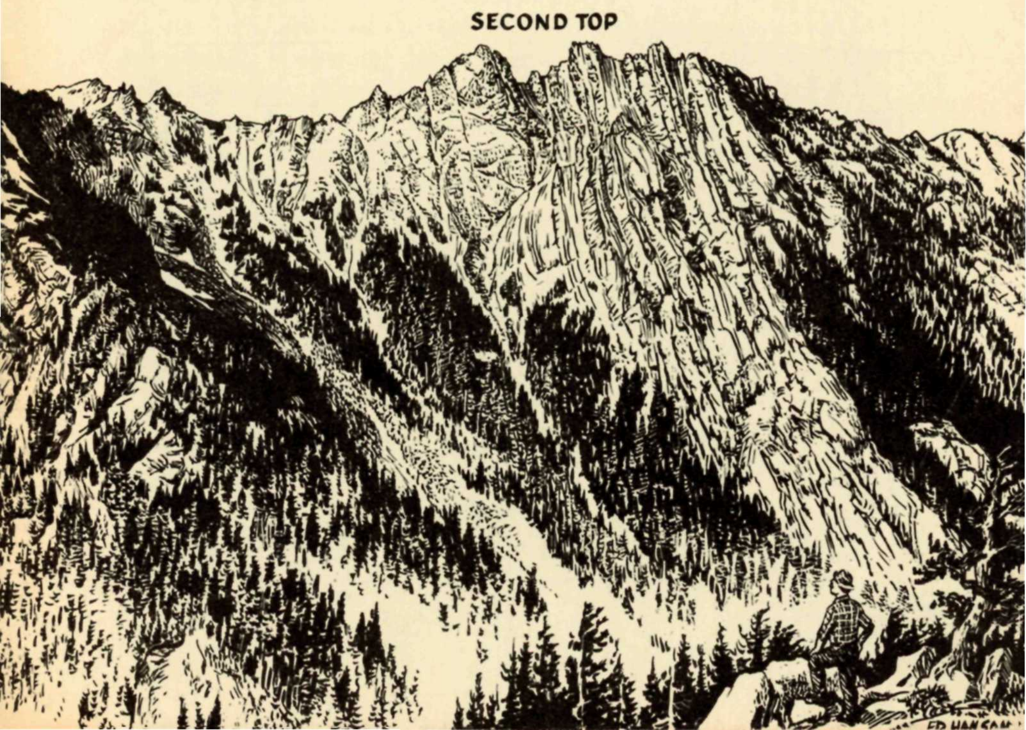
GEOLOGIC GUIDE TO THE HURRICANE RIDGE AREA



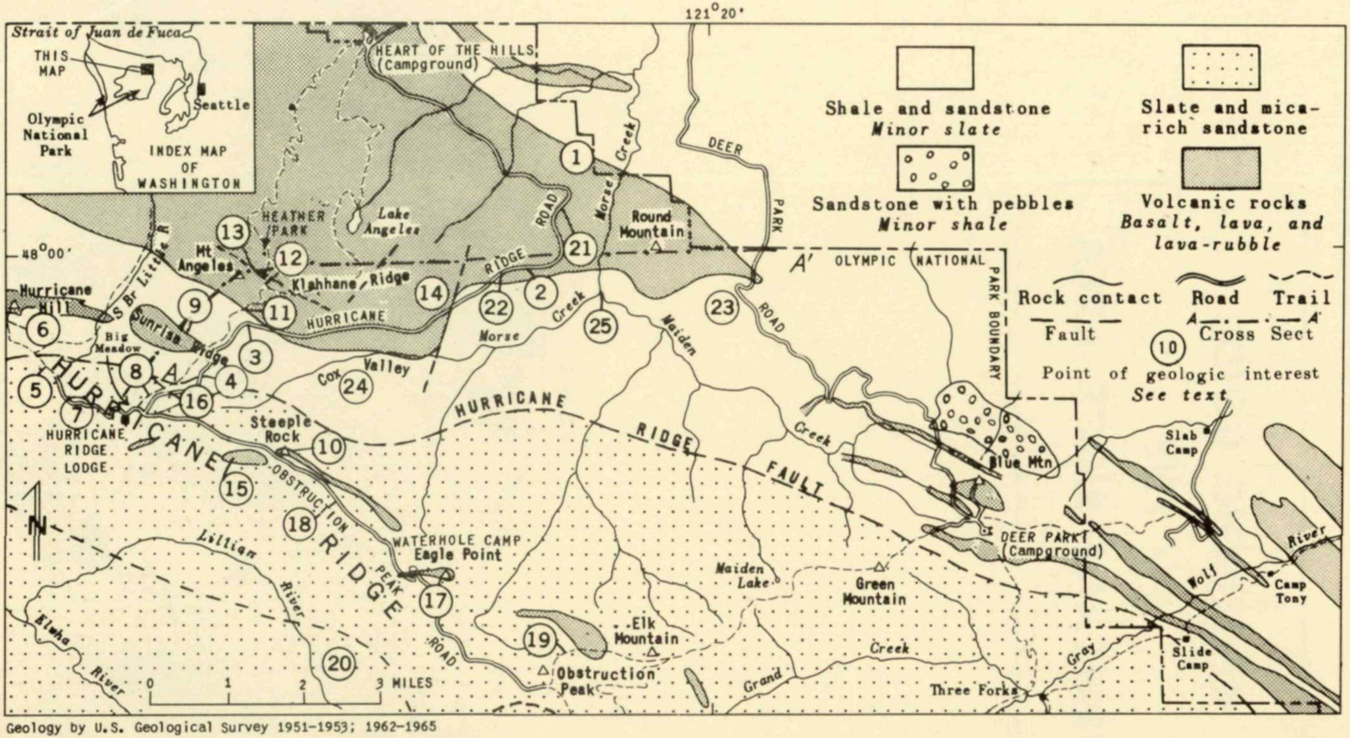


fig. 1. Simplified geologic map of the Hurricane Ridge-Deer Park area.

GEOLOGIC GUIDE TO THE HURRICANE RIDGE AREA

by

ROWLAND W. TABOR

U.S. Geological Survey, Menlo Park, California

Drawings by Ed Hanson

Publication authorized by the Director, U.S. Geological Survey

* * * * * * * * * * * *

INTRODUCTION

Most travelers enjoy only a brief visit to Olympic National Park and thus form only a passing acquaintance with the mountains. But even a short visit can make a lasting impression if the visitor learns a little about the mountains, the details of their flowers, animals, seasonal moods, and the geologic events and processes that have gone into forming the mountain scene. With a human acquaintance, the more we learn about his past and the events that have made him what he is, the more interesting he becomes. So it is with mountains. I hope that this guide will help the visitor feel that the Olympic Mountains are more than a passing acquaintance by showing a bit of what makes the mountains the way they are. The discussion here is local; for a more expansive treatment of the geology of the Olympics the reader is referred to my Geologic Guide to Olympic National Park (University of Washington Press, Seattle, 144 p.).

Contents

	Page
Introduction	1
THE MAKING OF ROCKS AND SCENERY	3
The Hurricane Ridge Road: Molten Rocks under the Ocean	3
The Hurricane Hill Trail: A Close View of the Ancient Ocean Bottom	6
Sand and mud on the ocean bottom	6
Folded rocks	7
Beginning of volcanism	7
View from the Lodge Terrace: The Wreckage from a Collision of Crustal Plates	8
The Mount Angeles Trail: Lavas and the Landscape	9
The sculpturing of the earth's crust	9
A rare mineral from the ocean bottom	10
The edge of an upside-down lava field	11
A giant fold	12
The Obstruction Peak Road: The History of Landscape	13
A collapsed mountain	13
Relicts of ancient scenery	14
The marks of gravity	14
THE WORK OF THE GLACIERS	16
Mountain Glaciers	16
The Cordilleran Ice Sheet	16
Ancient Lake Morse	18
A change in the course of Morse Creek	18
Conclusion	20

THE MAKING OF ROCKS AND SCENERY

The Hurricane Ridge Road: Molten Rocks under the Ocean

On the Hurricane Ridge Road (fig. 1) the traveler will find ever-improving vistas as he drives up the winding road, but the rocks along the road themselves are worth a look, for they reveal an interesting story of the mountains' past. The traveler really becomes aware that the Olympic Mountains are made of rock at Lookout Rock (4.2 miles from the Heart O' the Hills entrance station) where
1**cliffs of gray-brown to red basalt lava flows rise high on the right as the road winds through tunnels and around sharp spurs. As the traveler proceeds up the mountain, he is heading for the ocean bottom that first received these outpourings from the earth's hot interior.

It would not be possible to go *up* toward the *bottom* if the lava beds were not tilted as they are here (fig. 3). Layering in the once flat-lying lavas which reveals this tilting is obvious in a few roadcuts, but the traveler may well wonder how it is known that the basalt lava came out on an ocean bottom. At several pre-
2 cipitous places along the route (especially at a winding stretch 5.6 miles from the station), the roadcuts along the side of Klahhane Ridge reveal some curiously rounded masses in the lava. The geologist calls these *pillows* (fig. 2), and they indicate that the lava poured out into water. Imagine the turmoil when molten

fig. 2. Cliffs of lava and volcanic debris high on Klahhane Ridge. The rocks near the man are breccias; those forming rounded masses above are pillow lavas.

**Marginal numbers refer to points of geologic interest on figure 1.

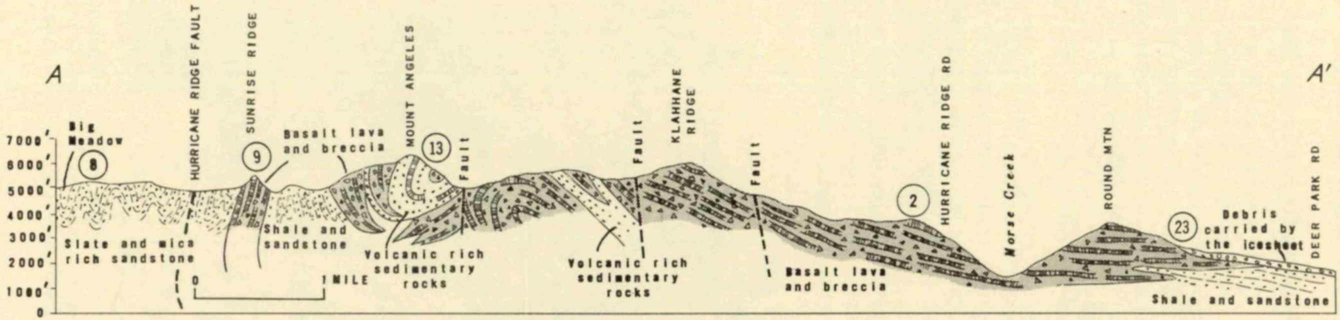


fig. 3. Generalized cross-section from Hurricane Ridge to the Deer Park Road showing the rocks underlying the Mount Angeles-Klahhane Ridge massif.

rock flows out of a fissure in the ocean bottom. The first bit of hot lava to come in contact with the seawater forms a globule, or pillow, its surface quickly cooled and hardened by the seawater. The lava in the core of the globule is still molten and sometimes bursts out of a crack in the pillow skin to form another pillow. Chains of such linked pillows can be found on some rock outcrops. More often however, single pillows form and roll down the side of a pile of accumulating volcanic debris to be mixed with the ocean muds.

In some roadcuts that reveal the basalt pillows are beds of bright red limestone. These colorful rocks were deposited as limy mud on the ocean floor between outbursts of lava; they derive their red colors from iron and manganese leached, or stewed, out of the still hot volcanic rocks. The limestones contain the tiny shells of one-celled ocean creatures known as foraminifera, barely discernible with a magnifying lens (fig. 4). The foraminifera indicate that these rocks were born at the bottom of the sea.

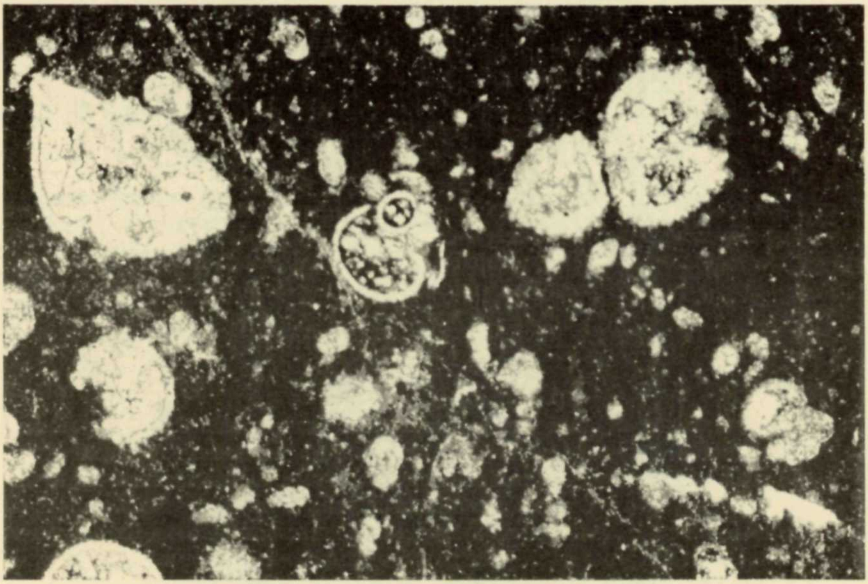


fig. 4. Fossil shells of foraminifera in red limestone. Enlarged about 30 times.

The basaltic rocks making up Mount Angeles and the ridges trending off to the west probably accumulated in a seamount, akin to the seamounts forming the islands of Hawaii. The entire Olympic Mountain massif is ringed on the north, east, and south by the upturned edges of basaltic seamounts that form high and rugged peaks and ridges.

As the road winds on toward the summit, the traveler catches glimpses of more volcanic rocks of the seamount, not always in the pillow form but more commonly as angular chunks and pieces bound solidly together in what geologists call a *breccia* (figs. 3 and 10). The breccias form both from the hot pieces of lava thrown from volcanic orifices and the loose rubble slumping off the growing volcanic pile. As the road approaches the earliest erupted beds at the base of the seamount, a few dark layers of shale can be seen between lava flows showing

that the volcanism in this spot began slowly and that normal ocean bottom
3 sediments were accumulating between eruptions. Finally the road crosses several closely spaced creeks (about 8.5 miles from the station) and one brush-filled avalanche track; beyond are continuous outcrops of dark shale and sandstone (fig. 1). At the time these rocks were deposited, between 40 and 60 million years ago, the ocean bottom here was serene.

Ribs of the well-bedded sandstone and shale decorate the road embankment for a few miles. Beyond the parking area for the Mount Angeles Trail, and beyond a grove of silvery trees in an old burn and just before a sharp corner where the road crosses a spur ridge is an open reentrant on the hillside channeling several streams (at about 10.5 miles). In this reentrant, instead of the even,
4 parallel beds of sandstone and shale are discontinuous pods and ribbons of sandstone in a flaky, shaly matrix. Look closely to find pieces of folded sandstone beds. Small faults, marked by black gullies of soft, groundup rock, cut down the faces of the roadcut. This zone of sheared rock marks the Hurricane Ridge fault, which separates the volcanic rocks of the Mount Angeles massif and their underlying ocean sediments from highly disrupted mica-rich sandstone and slate of the Olympic core (fig. 1).

The Hurricane Hill Trail: A Close View of the Ancient Ocean Bottom

SAND AND MUD ON THE OCEAN BOTTOM

A rewarding place for a leisurely stroll is along the trail to Hurricane Hill, with vistas of snowy peaks on one side and nearby views of flowers and rocks on the other. Along one side of the old roadcut that now serves as the trail, the stroller can see a wall of rocks, distinguished by an even alternation of light micaceous sandstone (fig. 5) and dark slate layers. Although these rocks are part

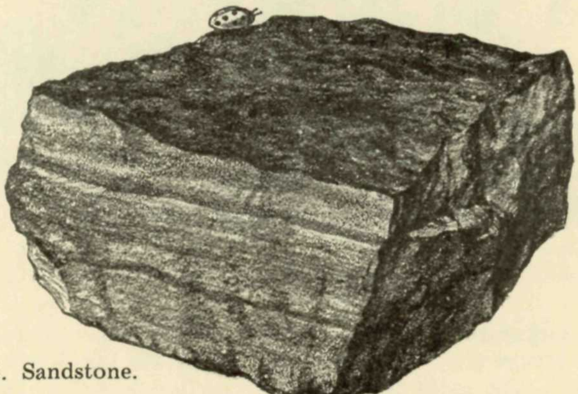


fig. 5. Sandstone.

of the generally disrupted Olympic core, they are relatively intact and reveal mud of their sedimentary history. Examine closely a few of the sandstone layers. The tiny sand grains that once settled on the ocean floor are easily seen. A close look at the darker layers is less rewarding, for the grains of mud from which this rock was formed are too small to see and are bound so tightly together that the rock is smooth and hard. The sands and muds of the ocean bottom became rock over a long period of time when compressed by the weight of overlying sediment and cemented by minerals precipitated from water between the grains.

FOLDED ROCKS

Because layers of sediment are deposited horizontally on the floor of the ocean, we must conclude that something remarkable has happened not only to tilt these beds but also to raise them so far above the sea. The tilted beds here are actually tightly folded in much the same fashion as the sides of an accordion. The existence of the earth forces that produced this folding is in evidence in the folded rocks of almost every mountain range in the world. The folds can be seen along the trail here if the observer looks carefully. The beds are not only folded but also highly broken up along small faults (fig. 6).

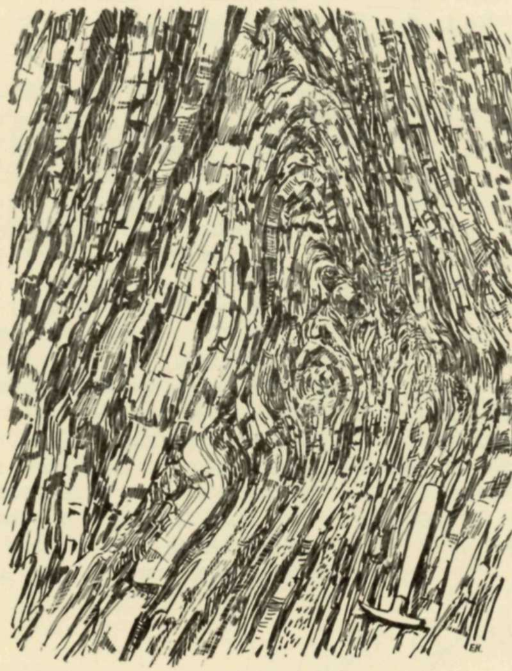


fig. 6. Fold in sandstone and slate along the Hurricane Hill Trail.

BEGINNING OF VOLCANISM

From the head of Little River where the trail crosses the hard-to-find Hurricane Ridge fault, the traveler leaves the disrupted rocks of the Olympic core and begins a traverse of relatively undisturbed rocks. As he progresses toward the summit of Hurricane Hill, he passes younger and younger beds. Rocks representing many thousands of years of slow sediment accumulation are
6 traversed as the trail rounds a point and emerges from a grove of trees, the summit of Hurricane Hill in sight. At the last climb, where the trail begins to zig-zag, the stroller reaches the first thin beds of volcanic rock that spilled out across the ocean floor some 40 to 70 million years ago. To the left these lavas make small rugged cliffs. Rubble weathered from alternating layers of dark

volcanic and sedimentary rocks are encountered all the way up to the gentle meadow on top of Hurricane Hill. Much of the volcanic rock here is sprinkled with white dots. A close look shows that the dots are small cavities filled with white minerals, mostly calcite and zeolites. The cavities were formed by gas bubbles escaping from the once molten rock. Later the zeolite and calcite precipitated from mineral solutions in the rock and filled these fossil bubbles. At the very summit, where the old fire lookout used to be, is a ledge of pillow basalt, much like that described along the Hurricane Ridge Road (fig. 2). The main mass of the submarine seamount, now tilted on end, can be seen on Mount Angeles across the valley to the east.

View from the Lodge Terrace: The Wreckage from a Collision of Crustal Plates

Southwest from Hurricane Ridge, ridges, valleys and snowy peaks lie in an impressive panorama. The viewer at the lodge stands near the margin and on the upturned edge of a series of very large rock slices (measured in miles) which have been swept off the ocean floor and piled under and against the resistant basaltic
7 mass that makes up Mount Angeles and Hurricane Hill to the northeast and other basalt masses to the east and south. There is nothing visible in the view to suggest this monumental event which probably took place between 20 and 40 million years ago; it is difficult, even, to see the rocks exposed under the trees and snow banks. But geologists have visited most of the ridges in view and determined the distribution of rock types in them, their ages, and the style of deformation. As far as the viewer can see are beds of sandstone and shale, contorted and sheared, sliced apart, and stacked up. The area of most intense deformation, where the original sediments have recrystallized to slate, phyllite, and other metamorphic rocks, is near the headwaters of the Elwha and its tributaries.

How the disruption of Olympic rocks relates to the earth's crustal unrest is shown in figure 7. The earth's outer shell appears to be made up of very large, somewhat rigid plates. Oceanic plates are generated along oceanic ridges by upwelling lava. They move outward away from the ridge and collide with or

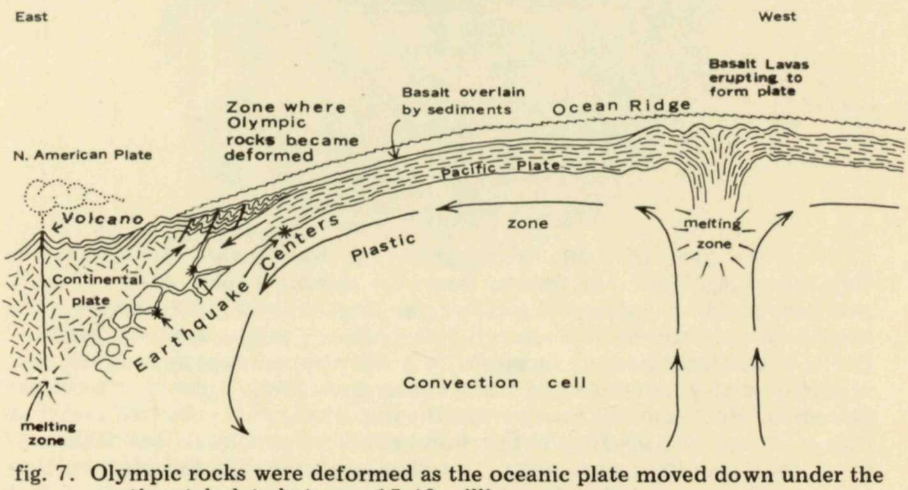


fig. 7. Olympic rocks were deformed as the oceanic plate moved down under the continental plate between 15-40 million years ago.

plunge under continental plates. The oceanic sedimentary rocks and basalts of the Olympic Mountains were deformed in the zone of collision as the Pacific plate, generated by the Juan de Fuca Ridge off the coast of Washington and British Columbia, descended beneath the North American plate some 15–30 million years ago. Through this process, material once part of the oceanic plate is converted to rocks welded onto the margin of continental plates; the continental plates grow. The panorama of mountains viewed from Hurricane Ridge is a small, new welt of material at the continent's edge. Olympic rocks have not been recrystallized and changed chemically enough to qualify as bona fide continental rocks, so we might guess that they are only a temporary welt, probably soon to be eroded and returned to the ocean for another episode of collision.

The Mount Angeles Trail: Lavas and the Landscape

There are two ways to reach the high shoulder of Mount Angeles. One trail leaves the Hurricane Ridge Road directly below Mount Angeles (at about 9.7 miles from the Heart O' the Hills station) and one branches from the nature trail on Big Meadow near the Hurricane Ridge lodge. The former is short and direct; the latter, round about and more scenic. We will examine some of the geologic features along the longer route.

THE SCULPTURING OF THE EARTH'S CRUST

When the hiker gains the crest of the long ridge joining Big Meadow with Mount Angeles, he begins to get a good view of the mountains all around him.
8 The rocks on which he stands were formed on the bottom of the ocean and pushed up to their present height by crustal forces, but the individual peaks and valleys have been sculpted by water and glacier ice. Over hundreds of thousands of years, erosion tears down the mountains. Some rocks are harder than others, and the resistance of each rock to erosion becomes accentuated as erosion progresses; hard rocks remain as bold ribs or rugged ridges, soft rocks wear away to form gullies and valleys. Thus the shapes and lines of peaks the hiker sees about him are dependent on the character of the rocks from which they were carved.

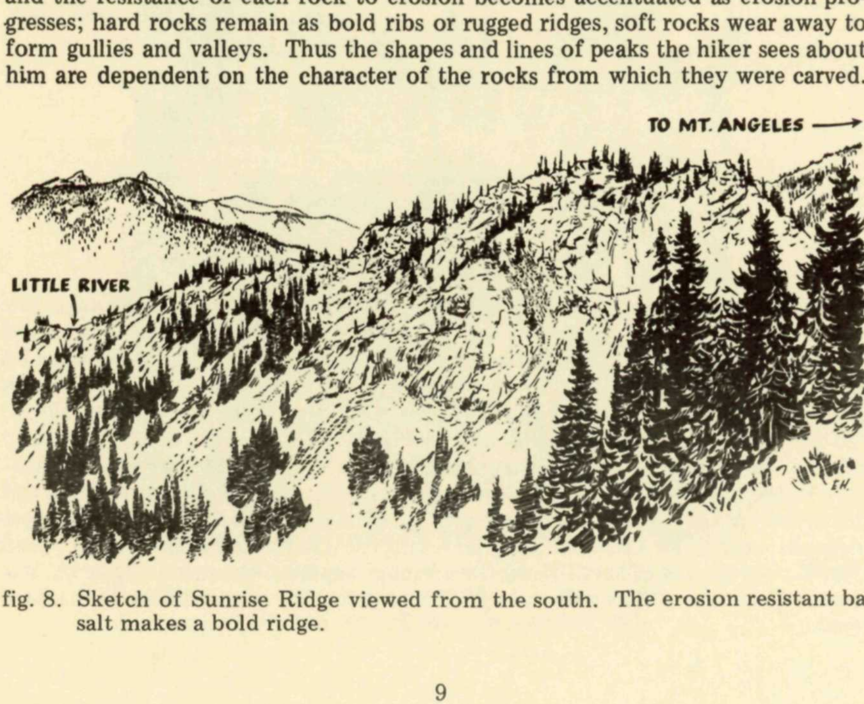


fig. 8. Sketch of Sunrise Ridge viewed from the south. The erosion resistant basalt makes a bold ridge.

Progressing along the trail, the traveler can look down to the north into the
glacier-carved cirques (bowl-shaped valleys such as seen in fig. 13) above the
Little River. Forming a west-trending spur between these cirques and Mount
9 Angeles is a rugged rib of rock called Sunrise Ridge (fig. 8). It is made of basalt,
the same volcanic rock investigated on the road and on Hurricane Hill, and is
more resistant to erosion than the soft shales and sandstones on either side.
Beyond Sunrise Ridge the resistant volcanic masses of Mount Angeles and
Klahhane Ridge rise high (fig. 2). Blue Mountain to the far right (southeast) also
owes its height to the resistance of volcanic rocks. The view to the south from
10 here is dominated by Steeple Rock, an imposing spine of erosion-resistant basalt.
On a clear day, rugged cliffs held up by the basalt layer can be seen extending
discontinuously along the mountain crest to Elk Mountain (fig. 9).

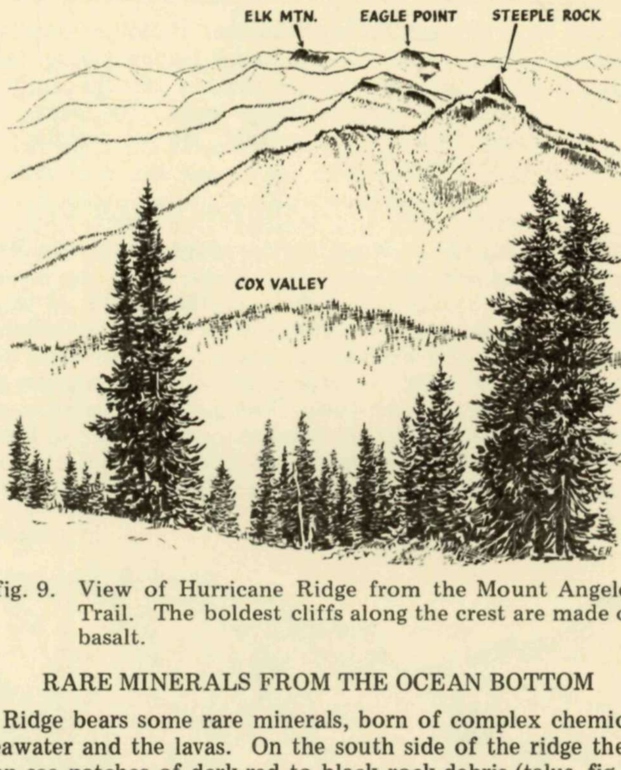


fig. 9. View of Hurricane Ridge from the Mount Angeles Trail. The boldest cliffs along the crest are made of basalt.

RARE MINERALS FROM THE OCEAN BOTTOM

Sunrise Ridge bears some rare minerals, born of complex chemical reactions between seawater and the lavas. On the south side of the ridge the sharp-eyed observer can see patches of dark-red to black rock debris (talus, fig. 8) made up of red limestone, jasper (a dark-red quartz rock) and small amounts of black minerals containing manganese, a valuable metal used in many modern alloys. To find such a dark patch of debris was the hope of prospectors in the early 1920's, for it might lead the prospector to large and valuable deposits of manganese ore. In the Olympics the manganese minerals usually occur in small and scattered masses, closely associated with volcanic rocks. Some of the manganese deposits near Lake Crescent were mined in the 1920's and again during World War II. Geologists of the Federal Government explored the peninsula in the war years of the late 1930's and early 1940's to assess the supply of the then scarce metal.

On Sunrise Ridge the manganese minerals occur in thin red limestone beds between laval flows, mostly on the west end of the ridge. Prospects in these deposits were given the rather unpretentious names of *F and L*, *Ella*, and *Broken Shovel*. The experienced mountain hiker who scrambles over to the ridge can recognize the rare manganese silicate rock by its black color, slightly metallic look, heaviness, and sooty coatings of manganese oxides. The exact origin of the manganese minerals is obscure even to the experts, but the manganese probably came from the hot lavas when they erupted. It was deposited in various mineral forms on the ocean bottom.

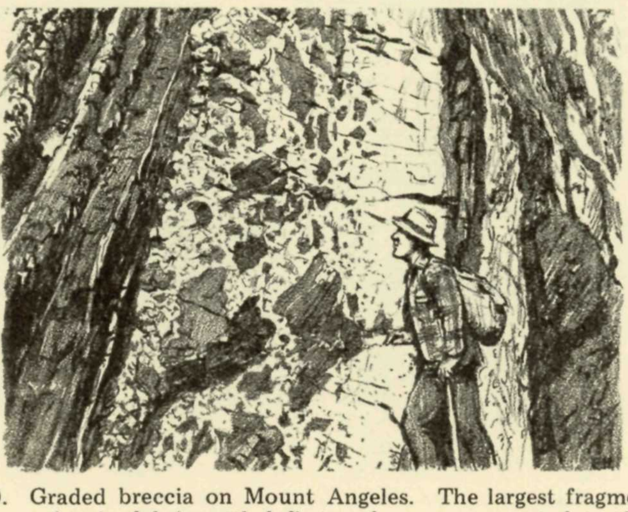
THE EDGE OF AN UPSIDE-DOWN SEAMOUNT

The hiker continuing along the Mount Angeles trail begins to get some handsome views of the volcanic rocks making up Mount Angeles just before he
11 reaches the junction with the cutoff trail coming directly up from the Hurricane Ridge Road. From this junction the trail climbs in steady switchbacks passing outcrops of dark-green volcanic breccia (lava rubble). Here the hiker climbs on the very edge of the uptilted volcanic field, for uphill towards Mount Angeles rugged cliffs of lava and breccia reign supreme while downhill in the opposite direction shales and sandstones hold up the meadows and fir thickets. The trail is red with the dust of iron- and manganese-rich ocean muds laid down among the lava flows.

The ridge crest and trail junction overlooking the Strait of Juan de Fuca bring
12 the most spectacular views of the volcanic rocks of the Mount Angeles massif. To the northwest on the shoulder of Mount Angeles, colorful beds of sedimentary rocks, rich in fragments of lava and alternating with beds of volcanic breccia, lean crazily towards the strait (see the cover to this book). The difference in resistance to weathering of each bed has produced startling ribs and flutes: thick beds of hard volcanic breccia stand up in straight walls; the soft beds of red shale make deep valleys.

The mountain traveler has two routes to choose from here: down the trail to Heather Park on the north ridge of Mount Angeles or up and along Klahhane

S



N

fig. 10. Graded breccia on Mount Angeles. The largest fragments of volcanic debris settled first and are concentrated to the left, that is at the bottom, of the now uptilted bed.

Ridge, eventually dropping down to reach Lake Angeles. The hiker heading for Heather Park can examine closely some of the bedded rocks on Mount Angeles by carefully skirting the outcrops above the trail.

When sediments are dumped into the ocean, the largest, heaviest particles or chunks tend to settle to the bottom first, the smallest last. The result of this
13 simple process can be seen in many outcrops of *graded breccia* (fig. 10) and tells us which side of a particular bed was originally up. These graded beds show that the lava field of Mount Angeles has not only been tilted up from its original horizontal position (fig. 3), but tipped over; it is partly upside down!

A GIANT FOLD

The hiker bound for Lake Angeles traverses a pinnacled ridge of volcanic breccia and pillow basalt. And if fog has risen on the north side of the mountain to make a dreamland of weird knobs and drifting mists, he may more easily be able to imagine a primeval world 70 million years ago when hot lava and lava rubble collected on the ocean bottom. But blue skies will reveal more clearly what has happened to these oceanbottom accumulations when they have been squeezed by the tremendous pressure of mountain building.

Once over the first goat-besprinkled hump east of the trail junction, the hiker
14 can view the lower reaches of Morse Creek valley and a giant fold in the bedded rocks composing Klahhane Ridge. The fold is not easy to see, but the eye can trace the position of the etched-out beds from place to place and reconstruct the once continuous bend of the fold (figs. 3 and 11).

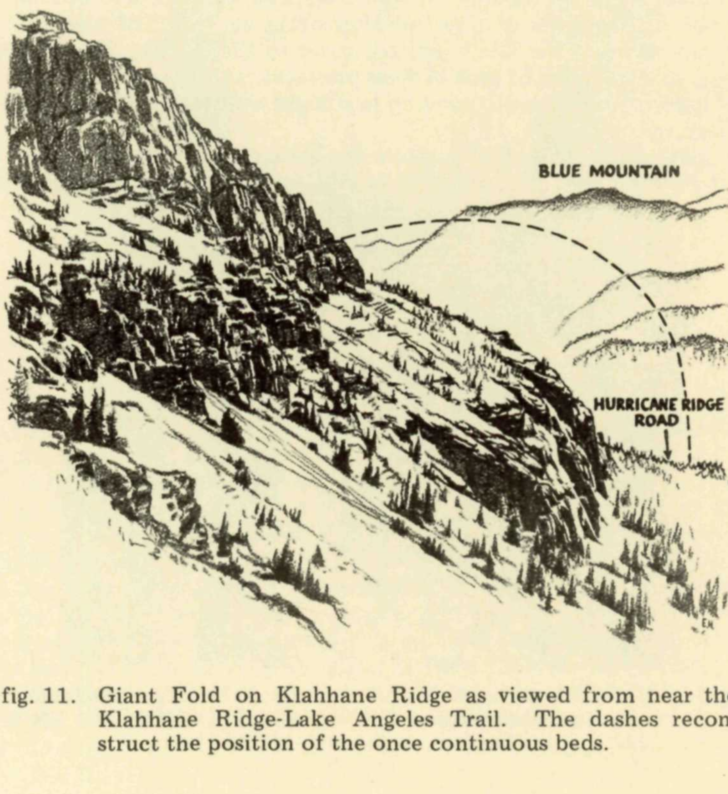


fig. 11. Giant Fold on Klahhane Ridge as viewed from near the Klahhane Ridge-Lake Angeles Trail. The dashes reconstruct the position of the once continuous beds.

The Obstruction Peak Road: The History of Landscape

The trip to the lodge at Hurricane Ridge gives a fine taste of Olympic scenery but, to really savor the mountains, the traveler must at least drive out to the meadows of Obstruction Peak (commonly called Obstruction Point).

A COLLAPSED MOUNTAIN

Most geologic processes are of barely comprehensible slowness, but a few are rapid and even catastrophic. Where the Obstruction Peak Road emerges from a winding descent in forest to balance precariously on a knife-edged saddle before the long hill up to the base of Steeple Rock (about 1 mile from the turnoff), the traveler can see some hulking forms of dark rock among the trees on the bumpy terrain to the west (right) (fig. 12). The explorer who wanders down among

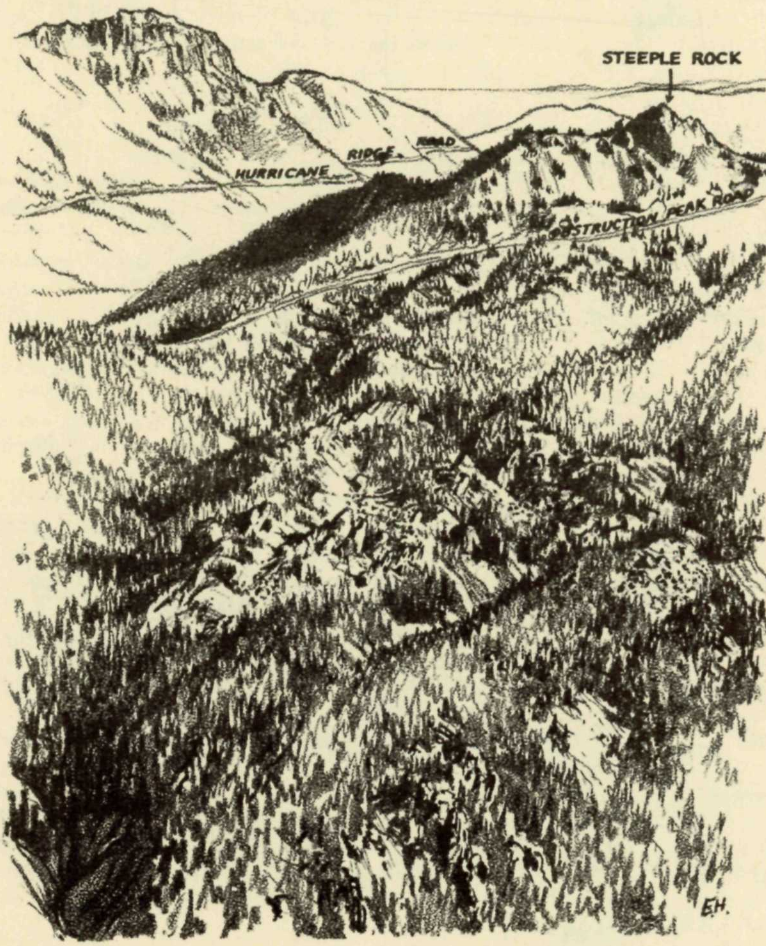


fig. 12. Rubble of the collapsed pinnacle of basalt near the Obstruction Peak Road.

these monoliths of pillow basalt will find a fantastic jumble of rock walls, blocks, and rubble piles. It is like the ruins of some gigantic city, overgrown and partially hidden by trees. What has caused this ruin? At the base of some huge mountain escarpment we would expect to find such debris fallen from the heights, but there is no such escarpment near here.

Up the road however, we find a clue to the ruin in the form of Steeple Rock,
10 an erosion-resistant pinnancle of basalt standing high above the rolling meadows of slate and sandstone. It is part of an uptilted layer of basalt extending several miles to the southeast (see figs. 1 and 9). The rocky ruin lies more or less along the same line to the northwest. Could not the rubble have once stood as a pinnacle like Steeple Rock? From the amount of debris we can surmise that the pinnacle was even larger. The cause of its collapse appears to be landsliding. As we will investigate further on in this guide, slippage of the surface layers of rock, especially in areas of weak slate or shale, is very common in the Olympics and such a slippage of the slates underlying a giant pinnacle could bring the whole mass tumbling down. What triggered the slide we can only guess, but heavy rains or an earthquake or both could have done the job.

RELICTS OF ANCIENT SCENERY

The gently rolling meadows near the Hurricane Ridge lodge or at Obstruction Peak contrast vividly with the steep nearby canyons; the meadowed surfaces may represent a relict landscape preserved from a time when the Olympic Mountains were gentler than they are today.

When a mass of the earth's crust is uplifted high above the ocean, streams form and begin cutting valleys in the elevated block. These newborn streams work hungrily and rapidly; the valleys they cut are steep. Eventually the valleys reach a maximum depth...the streams cannot cut deeper than the level of the sea to which they flow. Ridge crests at this time reach their maximum sharpness. But now slower erosive processes such as the washing of rain and small rills, the downhill creeping of loose soil and rock debris, and landsliding become the dominant agencies lowering the mountains; the sharp ridges begin to be rounded and smoothed, the steep valley sides become flattened.

It would appear that sometime in the past the Olympics had gained this stage in the erosive cycle and the ridges were smoothed into rolling highlands. But before the agencies of rounding and smoothing had a chance to reduce the mountains to uninteresting lowland hills, two things happened: the range was glaciated and it was uplifted again. We will discuss the glaciation in more detail in the next section, but in general glaciers are even more ravenous than youthful streams when it comes to leaving steep-sided bites in the mountainside. The glaciers have been most effective in removing all traces of the old gentle upland on the north sides of ridges. The uplift, however, gave the streams new appetite and they once again began steepening the valleys and sharpening the ridges. Much of Hurricane Ridge preserves the old gentle upland, but here and there the energetic streams have completely removed the gently meadows; for instance where the Obstruction Peak Road first leaves the meadows near the lodge and clings to a breathtaking new slope, and where the road climbs in steep switchbacks up toward Eagle Point, above Waterhole Picnic Area. The break in slope between the ancient meadowed upland and the newly made steep valley sides is best observed from the air (fig. 13).

THE MARKS OF GRAVITY

The slow erosion processes that produced the ancient upland are still active

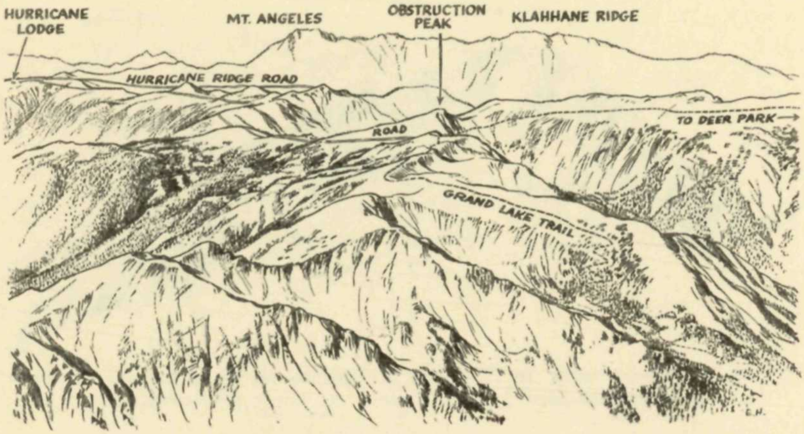


fig. 13. Aerial view of Hurricane Ridge, looking north. The old upland surface can be seen to the left near the ridge crest, steep valley sides below. Newly cut glacier cirques on the east side of foreground ridge.

today, and some of the features seen along the Obstruction Peak Road reflect these processes.

18 Look along the downhill side of the road between Steeple Rock and Waterhole Picnic Area for shallow swales (fig. 14); the road itself follows along them in places. These are creep depressions formed when soil—weathered rock debris—or masses of bedrock move slowly downhill by gravity (fig. 15). This movement can bend steeply tilted underlying beds of rock. The hiker on the high ridges in

fig. 14. Sidehill depression caused by creep along the Obstruction Peak Road.

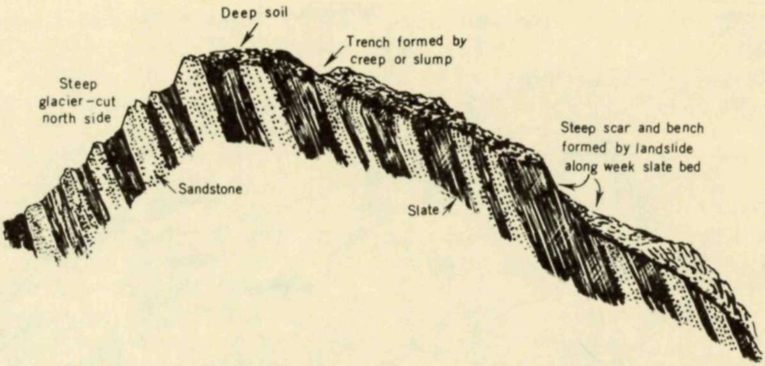


fig. 15. Idealized ridge in Olympic Mountains showing creep and landslide topography on south side and steep glacier-cut north side.

the Obstruction Peak area will find pronounced linear ridge-top depressions, some approaching small valleys in size. Creep and landslide processes have also produced flat benches far down on the steep valley side and may well have caused the collapse of the ancient giant pinnacle northwest of Steeple Rock.

This same erosional activity can be noticed on high alpine trails in the Olympics, especially those traversing the south side of ridges. In the spring the
19 hiker may encounter peculiar downward sags in the trail; there may even be a complete break. The creep of the upper layers of soil and rock rubble has carried the trail downhill with it. The break is soon mended by the passage of boots but the hiker may wonder why the route is so erratic.

THE WORK OF THE GLACIERS

Mountain Glaciers

The present-day Olympic Mountains owe much of their ruggedness to the glaciers that eroded them during the Pleistocene Ice Age. Almost every major valley and northside tributary were deepened and steepened by the glacial erosion.
20 The steep-sided valley of the upper Lillian River, the bowl-shaped cirques on the north side of the Hurricane Ridge (fig. 13), and the bigger cirques on the north and east sides of the ridges to the west all demonstrate the style of glacier sculpting. Far off to the west on Mount Carrie and Mount Olympus, the shining ice and snow of today's glaciers give hints of how the whole range looked some 18,000 years ago.

The Cordilleran Ice Sheet

The most dramatic glacier story of the Olympic Peninsula is of the great Cordilleran Ice Sheet that at one time lay to the north. At several places accessible from the Hurricane Ridge area, such as the summit of Hurricane Hill, the Mount Angeles-Klahhane Ridge, and the view points along the Hurricane Ridge Road, we can let our imagination recreate the time of the Ice Age. From these view points, we can look to the north out over plains and waterways where lay the southern margin of the ice sheet about 15,000 years ago.

Clues to the existence of this great ice mass can be found along the Hurricane
21 Ridge Road. Just above the tunnels (about 8.6 miles from the lodge) along the roadside is a mound of gravel and boulders tumbled off a large gravel bank above

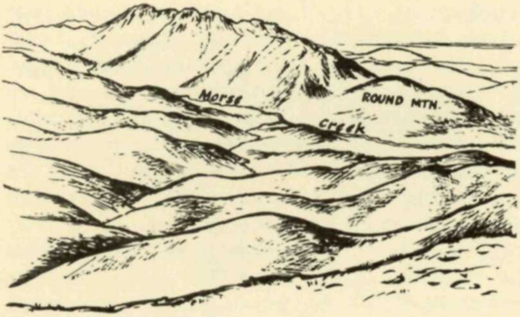


fig. 16A.
Before ice age glaciation. Morse Creek flows east by Round Mountain.

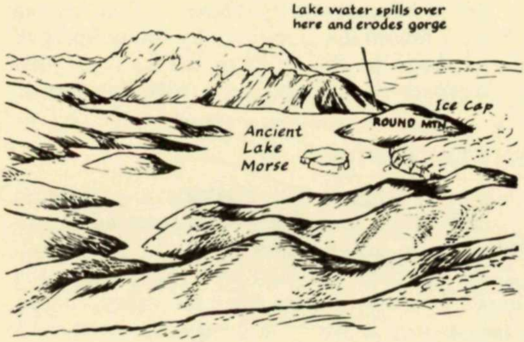


fig. 16B.
Ancient Lake Morse formed at edge of Cordilleran Ice Sheet. (Ice Cap)

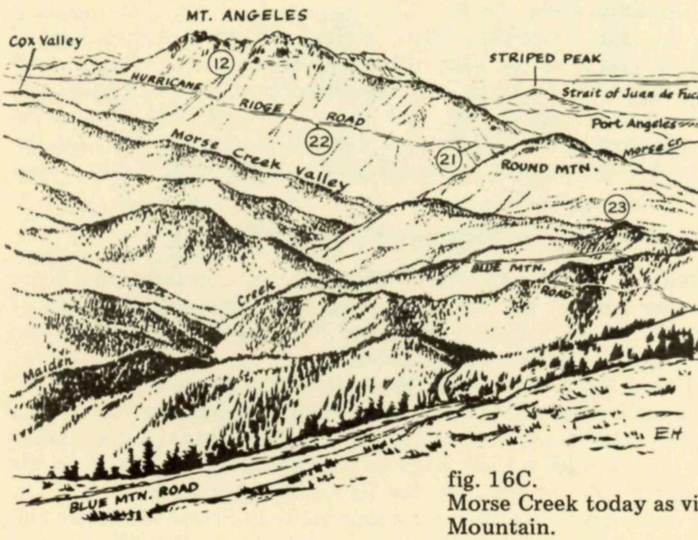


fig. 16C.
Morse Creek today as viewed from Blue Mountain.

the road. A few of the larger boulders here are of white granite, a rock type characteristic of the North Cascade Mountains and British Columbia Coast Ranges, but as far as is known, occurring nowhere as bedrock in the Olympics. These boulders must have been brought here by the Cordilleran ice and are common up to elevations of about 3,500 feet all around the north and northeast end of the Olympic Mountains. We can visualize the great mass of ice pushing up and around the dam of the Olympics, one branch of ice flowing out along the Strait of Juan de Fuca to the sea, the other flowing south in the Puget lowland beyond the city of Olympia, where the advancing ice finally melted.

A good place to contemplate the meaning of these foreign boulders is from
22 the established viewpoint on the Hurricane Ridge Road (6.3 miles from the
lodge). To the east we can see tree-covered flats on a broad, low divide between
23 the ridge of Blue Mountain and Round Mountain (fig. 16). The edge of the ice sheet pushed across the divide between the two mountains, for this area is covered with debris left by the ice, and the slopes leading westward into Maiden Creek are veneered with sand and gravel carried by meltwater streams. In fact, we can see rounded outcrops of lava on Round Mountain, smoothed by the scraping of ice. Round Mountain itself owes its shape to the work of the ice sheet that probably covered it for a time. Compare its smooth shape with the jagged, unglaciated cliffs of Mount Angeles.

ANCIENT LAKE MORSE

The story, however, is not finished. More granite boulders are scattered throughout Morse Creek Valley, its tributaries, and all the other forested valleys south of the Hurricane Ridge Road up to an elevation of about 3,500 feet. Although we might imagine that these boulders, too, had been carried in by the ice sheet, we find no other evidence of the glacier having filled the valley, that is, no rounded knobs and smooth ridges as seen in the other places that were overridden by the ice.

But if there was no ice, how did the boulders get there? The most plausible answer is that the valley was filled with a lake at the toe of the ice sheet (fig. 16B). Icebergs, breaking from the ice, laden with foreign rocks and gravels, floated out into the lake where they slowly melted and dumped their load of debris to the bottom, far from the edge of the ice. Such ice barges have indeed been observed in present-day northern latitudes where ice sheets and glaciers still reign. And it seems only logical that, with the ice pressed close around the mountain front, the streams draining the mountain would be dammed. On the hillside below Round Mountain, we find mud deposits typical of quiet lake waters at the front of glaciers.

A CHANGE IN THE COURSE OF MORSE CREEK

The ice sheet and lake can explain some of the landscape seen today, but there are still two peculiar features not so easily explained. One is at the head of
24 Morse Creek, where the Cox Valley is broad and flat, singularly different from the narrow high valleys of the Morse Creek tributaries.

A second is the odd bend that Morse Creek takes, as a glance at figure 1 will
25 confirm. Flowing for several miles in an east-northeasterly direction, eroding its valley in the relatively soft shale and sandstone, it suddenly takes a sharp swing to the north and cuts through a thick ridge of resistant lava. The drive on the Hurricane Ridge Road will impress upon the visitor the abruptness of the gorge made by this cut. But look again at the low divide between Round Mountain and Blue Mountain. The divide is suggestively in line with Morse Creek's eastward

course, and if we take the bends out of Morse Creek and chart the elevations of the creek bed along a line extending from its headwaters above the Cox Valley across the low divide, south of Round Mountain, we find that the divide lines up vertically as well as horizontally with the flat bottom of the Cox Valley (fig. 17). This suggests that the Cox Valley and the low divide are both parts of a once-continuous valley.

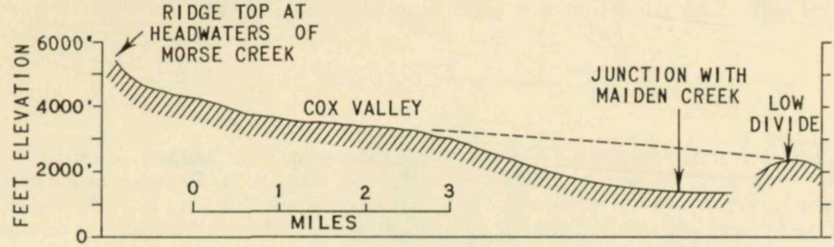


fig. 17. Elevations along the bed of Morse Creek. Dashed line shows course across the low divide.

To explain this change in the creek's course we might put all these observations together into a tentative and no doubt greatly simplified history. At one time, before the continental ice filled the lowlands to the north, Morse Creek flowed northeast around the south side of Round Mountain, thence out north to the Strait of Juan de Fuca (fig. 16A). Its position here was determined by a long history of erosion, during which time the relative hardness of the lavas of the Mount Angeles-Round Mountain ridge caused the ridge to stand out above the valleys eroded into softer rock.

When the ice sheet grew and advanced to block Morse Creek, a lake was formed that eventually spilled over the lava ridge just west of Round Mountain, probably following a course to the strait between the ice sheet and the mountain front (fig. 16B). When the ice began to melt away, as world climates warmed up, Morse Creek was trapped. It had cut a notch in the hard lava ridge and was already lower than its old course across the low divide. As it cut an ever-deepening gorge through the lava, the lake drained away. And in fact, we must imagine the land rising to some extent as the great weight of ice was removed from it; thus the creek cut well below its ancient course. In a sense, the Cox Valley and the low divide south of Round Mountain are fossil remnants of the ancient Morse Creek Valley.


EAST RIDGE
MT. ANGELES
MT. ANGELES TRAIL

GEOLOGIC GUIDE TO THE HURRICANE RIDGE AREA