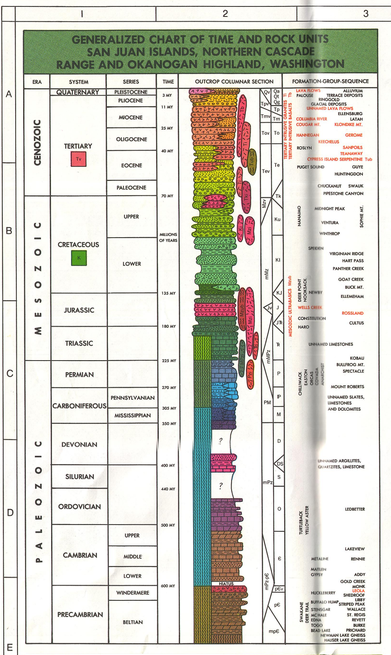
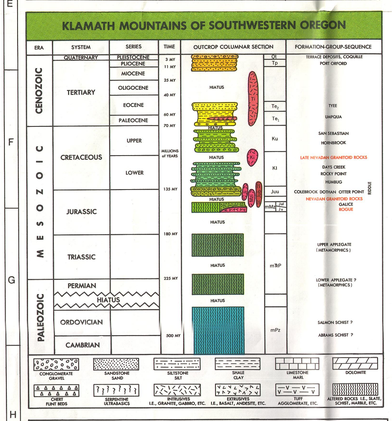
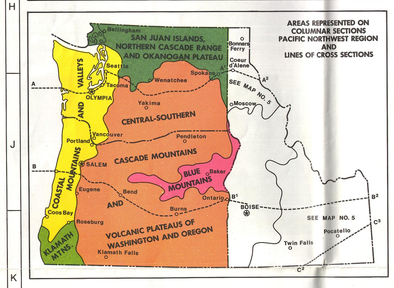
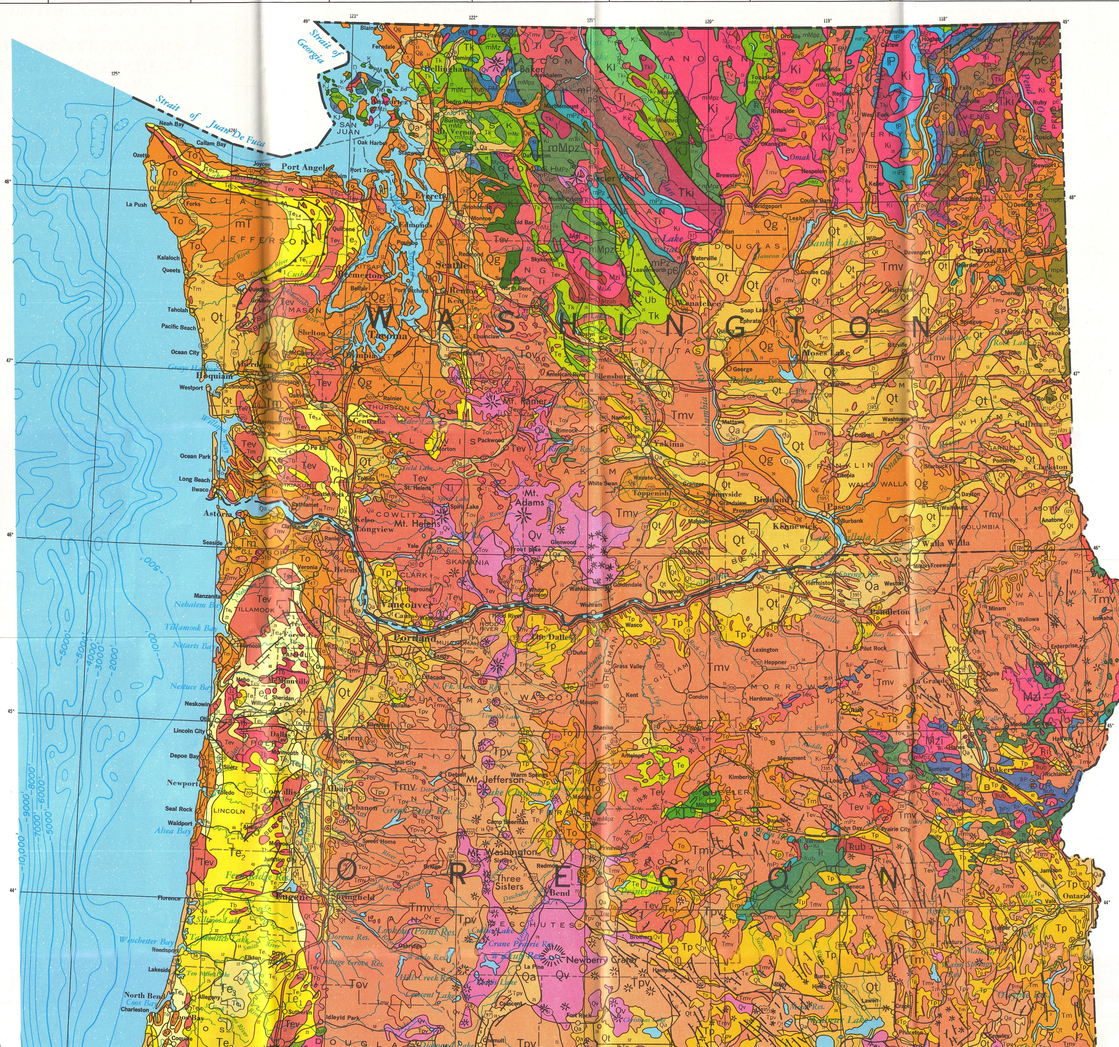








HOW TO STUDY THE EARTH WHILE YOU DRIVE ITS HIGHWAYS

Travel along the highways of Oregon and Washington can be an enjoyable geological experience irrespective of your training in earth science. The main purpose of this map and text is to guide you in this endeavor. In essence, we are actually moving over the skin of a dynamic medium-size planet encircling an average star. This skin, or the surface of its crust, consists of soils and rocks that were made in different ways over long periods of time reaching back in northeastern Washington and southwestern Oregon to at least a billion years; but generally, most rocks to be seen are much younger—commonly formed about 15 to 50 million years ago during the Tertiary Period. Beneath this rockscape you will discover, on probing, a complex record of many rises and falls of the seas, plains, and mountains, of advances and retreats of glaciers; and of frequent volcanic eruptions—all of which may interrelate to great shifting blocks of the earth's crust, both continental and oceanic.

USE OF THE COLOR AND SYMBOL CODES

Limitation of space permits only a few of the more interesting highlights to be noted. The main map on this page shows the age and outcrops of the surface rocks over which you drive, build, look, and live. This has been done by using various colors and symbols to identify rocks of different ages.

Along the sides you will see columns of time and rock units for five different areas of the map. These show the probable age of the rock group shown with a particular color—generally those used by the United States Geological Survey—and a particular letter symbol. For example, green areas with a capital "K" are Cretaceous rocks formed 70 to 135 million years ago. Locally a second lowercase letter further divides the age—"u" to indicate the upper (younger) subdivision and "l" for the lower (older) part. A special case is the Tertiary Period, whose particular epochs are denoted by letters—Te for Eocene, To for Oligocene, Tm for Miocene, and Tp for Pliocene.

Other devices are used to differentiate between the major classes of rocks—"m" for metamorphic or altered rocks, "s" for sedimentary, and "?" for igneous. Igneous rocks are shown everywhere in some shade of red—the color of molten lava. Again, each hue is indicative of a specific period of time, and a letter symbol also is employed. Igneous rocks may be formed either on the surface (extrusive or volcanic—"v") or below the surface (intrusive—"i"). Two other special types are "b" for basaltic intrusives and "ub" for ultrabasic (ultramafic) rocks such as serpentinite.

A broader time grouping of rocks is necessary in places. This involves the use of the symbols Pz for rocks of the Paleozoic Era, Mz for Mesozoic, and Cz for Cenozoic.

At the other extreme, a narrower grouping of rocks has been necessary—such as Te1, Te2, Te3, and Te4—for progressively younger divisions of the Eocene. In the Quaternary Period, Qa stands for alluvium along streams, Qt for terrace or tectonically tilted or elevated deposits, and Qg for glacial-related deposits.

Also in the columns of time and rock units, graphic representation of rock types is shown. These patterns are explained in a separate legend. Limestone is shown by a brickwork pattern, sandstone by dots, shale by dashes, conglomerate by circles, etc. Igneous and metamorphic rocks are also indicated by appropriate symbols.

Names of groups, formations, and sequences of rocks are given on the right side of each column. Only the more common ones are shown because of the limitation of space, and these are arranged as nearly as possible in their time and spatial framework.

With this edition, a series of references appears on the right side of the map front; these articles give useful facts for geologically oriented visitors to the Northwest National Parks.

MATERIAL ON THE BACK

A *landform* map shows the broad picture of the Oregon and Washington area such as you might observe from a space station in orbit on a clear day, and shows the broad layout of mountains, forests, seas, lakes, and deserts together with the names of the more prominent features.

A *structural-framework* map reveals the fundamental geologic structures, such as the major folds, faults, volcanic peaks and areas that are rising and subsiding.

A *genotype* map should excite any dedicated rockhound to reach for his pick and hammer. One should remember that a gem is not merely beautiful but tells a story of great earth changes.

Places of geologic interest and *selected field localities* are unusually plentiful throughout Oregon and Washington, and should provide added enjoyment and enlightenment in travel through the area. These relics of the earth's past intimate what a younger earth may have been like.

A series of small maps show an interpretation of *sea and land changes* through the ages in Oregon and Washington. Fortunately for Man, most of the large tides and movements in the crust that control the earth's geography occur slowly through millions of years, and thus are not noticed in the lifetime of an individual. In the recorded history of man during the last 4,000 years, the largest movements exceeded 10 feet in only a very few places.

At the bottom are the *cross sections*. These are aligned wherever possible along the nation's highways in order to give you a picture to a depth about 2 miles below the surface. Using this vertical cross section of the rocks together with the map showing their surface arrangement, you can conjure in your mind a broad three-dimensional model of the regional geology.

The cross sections also include the neighboring state of Idaho, the geology of which is shown on Map 5, the Northern Rocky Mountains.

To serious-minded geoscientists this map, because of its small scale, will prove inadequate for detailed study. However, it should be helpful for broad reference and orientation.

What is the purpose of this map? It is to remind everyone, whether he be a professional geoscientist or an interested tourist, that the earth is a unique and exciting place, and yet, measured against infinity and eternity, a finite and fragile object. We must all become stewards of the earth, and in order to do so we must understand it; and geology is the very foundation of this understanding. All life and the atmosphere relate to it, and the history of both is written into the rocks.

OVERVIEW—PACIFIC NORTHWEST

The now-dormant volcanoes of the Cascade Range with their living glaciers, the Pacific surf pounding relentlessly at slowly receding sea cliffs, and the powerful Columbia and Snake Rivers cutting ever deeper gorges into rocks of all ages from billion-year-old metamorphosed Precambrian sea deposits to thousand-year-old basaltic lavas—all attest to the dynamics of the geology of the Pacific Northwest, especially as compared to the geological quiescence of the Mid-Continent area. When one inquires into the reasons for this considerable contrast, it becomes obvious that the position of Oregon and Washington along the Pacific "ring of fire" is a prime cause. This ring of fire relates to the crustal instability and resultant volcanoes and earthquakes along the entire periphery of the Pacific shoreline. According to geophysicists, this instability arises from the juxtaposition of two vastly different crustal materials—the thick, relatively light crust of the continent versus the thin, relatively heavy crust of the Pacific Ocean basin. Many geoscientists claim that the oceanic crust may be expanding and slipping below the continental edge, which in part by destroys in the process. Another theory that has enjoyed long popularity is that seaward growth of continent-derived sediments and volcanic rocks over the oceanic margins is the dominant process, and that crustal instability results from excessive sedimentary loading of the crust and mantle that leads first to vertical adjustments and later to outward thrusting of the upward-growing fault blocks.

A broad generalization is that the oceanic strandline has been moving jerkily westward for many hundreds of millions of years—jerkily, because many small advances and retreats of the strandlines decipherable in the rock records are superimposed on this westward trend. Precambrian and Paleozoic sea deposits are scattered throughout Idaho, northeastern Washington, and parts of Oregon. Sea deposits became increasingly limited to the central and western half of the Washington-Oregon region during the Mesozoic. For example, early Cenozoic marine deposits have their eastern limits in the Puget Sound and Willamette Valley lowlands, and the late Cenozoic deposits largely are limited to the modern coastal environment.

Continental facies, involving deposits of floodplains, swamps, glacial melts, and volcanic fallout debris and flows, generally extend east of the sea (marine) deposits except where removed by erosion. These continental facies dominate much of the landscape east of the Cascades, where they have been preserved in interior basins that adjoin rising mountain ranges.

This simple arrangement of sediments is complicated by many volcanic and mountain-building events throughout more than 1 billion years of geological time. The first known volcanic events resulted in the extrusion of Lesla lava flows in the late Precambrian. Since then the geological record shows periodic buildups of offshore volcanic islands such as are known in modern western Alaska. The latest Cascadian volcanic event occurred at Lassen Peak across the border in California, in 1915.

Mountain-building episodes (orogenies) are numerous. These included much mobility in the late Devonian Antlerian orogeny, the Late Permian to Triassic movements, the Late Jurassic to mid-Cretaceous Nevadan orogeny, and the middle Tertiary Cascadian uplift with granitic intrusions and metamorphism.

Although it may not be apparent from this simplistic overview, the actual picture is a very complex one that has required many thousands of man-years of geological mapping and laboratory investigations to decipher.

PRINCIPAL SOURCES OF MAP INFORMATION

Geology adapted from: the Tectonic Map of the United States (USGS-AAPG, 1962); the Geologic Map of Oregon (USGS and Oregon Dept. of Geology and Mineral Industries, 1967, 1:2,000,000); the Geologic Map of Washington (Washington Div. of Mines and Geology, and USGS, 1961, 1:500,000; and 1969, 1:2,000,000); Geologic Map of Oregon West of the 121st Meridian (USGS and Oregon Dept. of Geology and Mineral Industries, 1961, 1:500,000); Preliminary Geologic and Tectonic Maps of Oregon East of the 121st Meridian (USGS and Oregon Dept. of Geology and Mineral Industries, 1978, 1:500,000 and 1:1,000,000). Manuscript maps of USGS, 1973. Various USGS maps of the MF, OQ, I, and GM series.

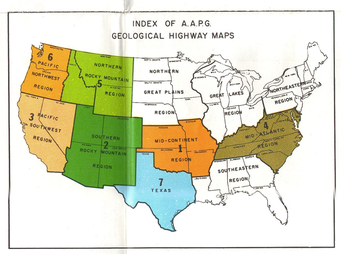
Geologic maps and publications of Washington, Oregon, and Idaho are available at nominal cost from the following. Lists of publications and maps are sent free on request.

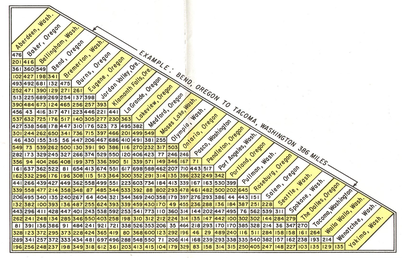
State Department of Geology and Mineral Industries, 1069 State Office Bldg., Portland, OR 97201
Department of Natural Resources, Division of Mines and Geology, P.O. Box 168, Olympia, WA 98504.
Idaho Bureau of Mines and Geology, Moscow, ID 83843

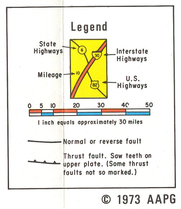
Topographic maps, geologic maps, and other publications of the United States Geological Survey on the western states are available from the United States Geological Survey, Denver Distribution Section, Bldg. 41, Denver Federal Center, Denver, CO 80225.

Maps and publications of the Pacific Northwest are available for sale over the counter only at the following places:

United States Geological Survey, South 157 Howard Street, Spokane, WA
United States Geological Survey, 555 Battery Street, San Francisco, CA
United States Geological Survey, 468 New Custom House, Denver, CO







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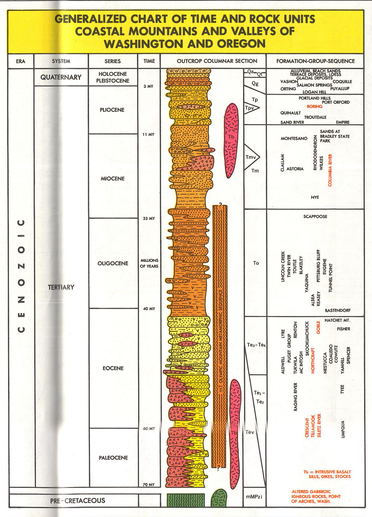
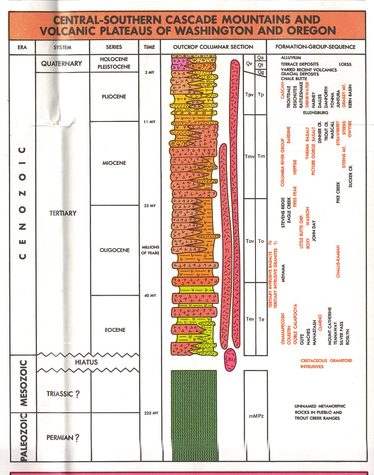
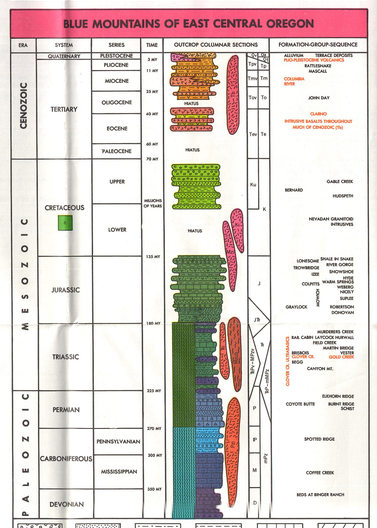






CRATER LAKE NATIONAL PARK

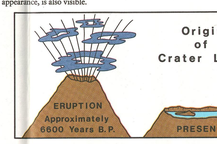
Crater Lake National Park was established in 1902, half a century after it was first discovered in 1853. There is an ancient Indian legend associated with the lake which states that Mount Mazama, from which the lake was formed, was a passageway between the worlds below and above. The chief of the underworld, Llao, had recently returned when his enemies dropped a mountaintop over the passageway, forever sealing him within. The resulting crater was filled with water and became a shrine of peace.

Crater Lake is truly a product of cataclysmic forces. Rising plumes of hot gases and molten lava from the lower part of the crust, perhaps as much as 20 to 40 miles deep, reached the surface during the early Pleistocene and began to form a great shield volcano, Mount Mazama. Its base overlies a partly eroded complex of overlapping accumulations of Pliocene volcanics which, in turn, lie on Miocene volcanic products, then Oligocene, and still older Eocene ashes and lavas.

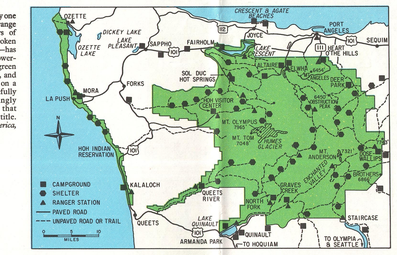
The present Crater Lake was formed when Mount Mazama exploded 6,600 years ago, covering the surrounding land with ejected debris and thus leaving the core empty. The sides of the volcano collapsed into the duct and formed the caldera, or Crater Lake. Since then, the lake has half filled the crater from rain and melted snow to its present level, which remains nearly constant through a balance of seepage, evaporation, and replacement by precipitation.

Before the explosion and collapse, Mount Mazama probably rose 2,000 to 3,000 feet above the rim of the present caldera, which now measures 5 to 6 miles across. These dimensions account for the 10 cubic miles of Mazama ash littering a vast surrounding area of the Oregon landscape. An additional 5 cubic miles of volcanic deposits probably collapsed into the caldera. This was one of the greatest volcanic explosions since Pleistocene time and was probably witnessed by the early Indian inhabitants, and thus accounts for their legend.

The lake is the deepest in the United States and the fifth deepest in the world. From it protrudes Wizard Island, a small cinder cone. After it was formed, lava poured from the sides and built a platform from the cone almost to the western wall of the caldera. The Phantom Ship, formed of hardened lava and so named because of its appearance, is also visible.



The Olympic experience is essentially one of wildness and timelessness. A strange natural phenomenon—great reservoirs of cloud swelled by a broad ocean and broken open on the heads of high mountains—has created the inexorable movement of powerful glaciers among misty peaks, the green dripping hush of the forest cathedrals, and the thunder and smash of the waves on a wild shore. It is a cornucopia of carefully preserved natural riches, strikingly uncrowded even today—a place that thoroughly deserves its Olympic title. Reader's Digest, *Scenic Wonders of America*, 1973, page 414.



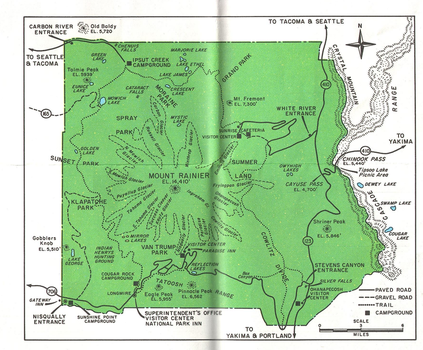
OLYMPIC NATIONAL PARK

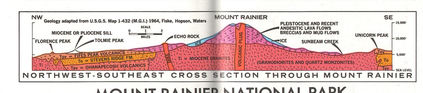
Olympic National Park, located on the Olympic peninsula, is a study of contrasts. In this one park are both mountain peaks and shoreline beaches as well as glaciers and rain forests. This remote corner of our nation was practically unknown until 1897, when it became a forest reserve. In 1909 the Mount Olympus National Monument was dedicated, and in 1938 the area became one of the national parks.

The park is a geological enigma. According to recent findings, the ancient-appearing hard slates and phyllites that compose the core of the Olympic range are rated among the youngest metamorphic rocks in the world—from early to middle Tertiary in age. These rocks were once thought to be much older. This premature aging presumably was caused by intense deformation in a geological process call "underthrusting," which occurred during the Miocene Epoch. Younger rocks were pushed below a rigid mass of older rocks and thus became greatly deformed and altered. The older rocks are mainly a sequence of pillow-lava flows that erupted upon the Pacific Ocean floor during the early Tertiary Paleocene and Eocene Epochs and incorporated some oceanic sediments. This sequence, known as the Crescent Formation, now forms picturesque bluffs in the northern and eastern portion of the park.

After Miocene time the Olympic Mountain core rose to its present lofty height and was deeply scoured by Pleistocene alpine glaciers, of which about 60 glaciers still remain.

Some geoscientists consider this series of events to be evidence for eastward thrusting of oceanic rocks of the Pacific Basin below the continental rocks of North America. Whatever the basic cause, the geology of this park represents some very traumatic events within the earth's crust.





MOUNT RAINIER NATIONAL PARK

Nothing quite prepares a person for a first view of Mount Rainier. . . There it is, a white cone that rears above the horizon like a phantom peak levitated on layers of cloud and hazy distance. Your first reaction is probably to pass it off as a tall buildup of clouds; look again and you realize it is Rainier, brooding over southern Washington just as Kilimanjaro's vastness rules the East African plain. For those who live within sight of it, it is grandly and simply "The Mountain." Reader's Digest, *Scenic Wonders of America*, 1973, page 421.

No American mountain outside Alaska is topped with more large glaciers than is Mount Rainier. Of these, Paradise Glacier exhibits all the usual characteristics of a typical alpine glacier including hanging valleys, cirques, and horns. Waters of streams that emerge from the many glaciers are generally colored a chocolate brown from the heavy rock-flour concentration with which they are laden.

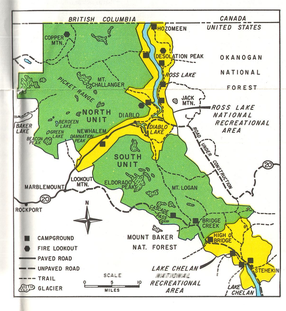
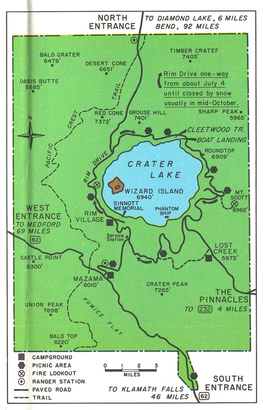
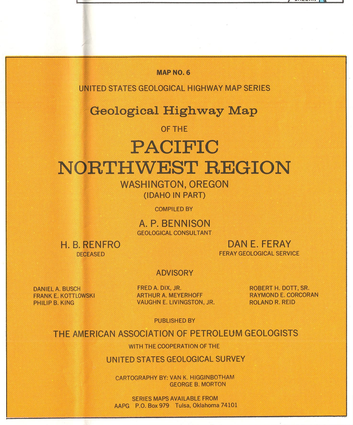
Mount Rainier is a young Quaternary volcano composed of thick lava flows interbedded with cinders, ash, rock rubble, and bombs. Although now dormant except for a few minor eruptions, the fires are still burning. Its shape is somewhat unusual for a composite volcano. Instead of having a slender point, it is broad and rounded.

Investigation around the base of the mountain reveals that much older volcanoes occupied this part of Washington—some during the Eocene, 40 to 60 million years ago, represented by the Ohanapecosh volcanic beds. During the Miocene, 16 to 18 million years prior to the Holocene, the Cascade Range was wracked by the Cascadian orogeny, leading to folds, faults, and intrusions of the Katoosh granites. After extensive erosion of these features, the infant Mount Rainier commenced its volcanic growth during early Pleistocene, over a great northwest-trending synclinal downfold known as the Unicorn Peak syncline. At the close of the Pleistocene it consisted of three peaks that were 1,000 to 1,500 feet higher than the present mountain. These peaks were largely obliterated by subsequent volcanic-related processes and gravity slides, and were replaced by the present cone.

Mount Rainier is justly famous for its beautiful fir forests and vast wildflower meadows that range up to 6,500 feet. Above this to the summit is a spectacular zone of barren rock and snow.

NORTH CASCADE NATIONAL PARK

Deep-seated cataclysmic forces have shaped our newest national park, which is located along the high divide of the northern Cascade Range. Its towering and glistening rock scarps, exemplified by Liberty Bell, are erosional remnants of extensive schist and gneiss terranes. These hard micaceous rocks were once normal sediments, volcanic flows, and ash beds of many ages ranging possibly from late Precambrian time to the early Mesozoic. These sediments accumulated to a depth of several miles in a deep, rapidly subsiding trough along what was then the Pacific shore. Violent earth movements during the Late Jurassic to mid-Cretaceous Nevadan orogenies 150 to100 million years ago severely faulted, contorted, and altered these rocks. Certain rocks were metamorphosed to granites either by great heat or by chemical action related to intruding granites.

During the Miocene Cascadian orogeny about 15 million years ago, these rocks were once more deformed and intruded by granites. Occasional volcanic eruptions following the Cascadian orogeny and the Cordilleran glaciation of the Pleistocene ice ages wrought still more changes on the northern Cascades, especially in the glacial gouging of the deep valley which is the setting of beautiful Lake Chelan and most other lakes in the park.

When you walk the paths of this park, reflect on the contrasts with Crater Lake National Park described below. Both regions belong physiographically to the Cascade Range, but their tectonic architecture differs radically. Crater Lake surmounts one of the greatest known piles of Cenozoic volcanic flows and ejecta—perhaps 5 to 6 miles thick—which accumulated in a great structural sag east of the Coast Ranges. North Cascade Park, on the other hand, is composed of much older and vastly different metamorphic rocks that have been arched upward episodically since Jurassic time. The explanation for this contrast is too involved for this column, but overviews of this phenomenon may be found in cited references.