

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science Directorate  
Geologic Resources Division



# Mount Rainier National Park

## *GRI Ancillary Map Information Document*

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Mount Rainier National Park

mora\_geology.pdf

Version: 6/4/2015

# Geologic Resources Inventory Map Document for Mount Rainier National Park

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## Geologic Resources Inventory Map Document



# Mount Rainier National Park, Washington

## Document to Accompany Digital Geologic-GIS Data

[mora\\_geology.pdf](#)

Version: 6/4/2015

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Mount Rainier National Park, Washington (MORA).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

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## About the NPS Geologic Resources Inventory Program

### Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

### Products

**Scoping Meetings:** These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

**Digital Geologic Maps:** Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>

**Geologic Reports:** Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage [http://www.nature.nps.gov/geology/inventory/gre\\_publications.cfm](http://www.nature.nps.gov/geology/inventory/gre_publications.cfm)

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: <http://irma.nps.gov/App/Reference/Search>. To find GRI data for a specific park or parks select the appropriate park

(s), enter "GRI" as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: <http://www.nature.nps.gov/geology/inventory>, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

## GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps for Mount Rainier National Park, Washington (MORA):

### **Digital Bedrock Geologic Map of Mount Rainier National Park, Washington (*GRI MapCode MORA*)**

Fiske, R.S., Hopson, C.A., and Waters, A.C., 1964, Geologic Map and Section of Mount Rainier National Park, Washington: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-432, scale 1:62,500 ([Geologic Map and Section of Mount Rainier National Park](#)). (*GRI Source Map ID 2081*).

### **Digital Surficial Geologic Map of Mount Rainier National Park, Washington (*GRI MapCode MORS*)**

Crandell, D.R., 1969, Surficial Geology of Mount Rainier National Park, Washington: U.S. Geological Survey, Bulletin 1288, scale 1:48,000 ([Surficial Geology of Mount Rainier National Park](#)). (*GRI Source Map ID 2077*).

Additional information pertaining to each source map is also presented in the GRI Source Map Information (MORAMAP) table included with the GRI geologic-GIS data.

## GRI Digital Bedrock Geologic Map of Mount Rainier National Park

### Bedrock Map Units List

The bedrock geologic units present in the digital geologic-GIS data produced for Mount Rainier National Park, Washington (MORA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qs - Surficial deposits). Units are generally listed from youngest to oldest. No descriptions for water or ice are provided. Information about each map unit is also presented in the Geologic Unit Information (MORAUNIT) table included with the GRI geology-GIS data.

### Cenozoic Era

#### Quaternary Period

- [Qs](#) - Surficial deposits
- [Qls](#) - Landslides
- [Qra](#) - Volcanic rocks/Andesite of Mount Rainier
- [Qroa](#) - Andesite of Mount Rainier, olivine andesite flows
- [Qrp](#) - Mount Rainier plugs and dikes

#### Tertiary Period

- [Tha](#) - Andesite of Bee Flat
- [Tw](#) - Welded tuff of The Palisades
- [Tg](#) - Granodiorite and quartz monzonite
- [Tdi](#) - Diorite, quartz diorite, granodiorite, and quartz monzonite porphyries
- [Td](#) - Diabase and basalt
- [Tf](#) - Fifes Peak Formation
- [Ts](#) - Stevens Ridge Formation
- [Tar](#) - Basaltic andesite and rhyolite
- [To](#) - Ohanapecosh Formation
  - [Tol](#) - Ohanapecosh Formation, accumulations of basaltic andesite flows and coarse mudflows
  - [Tor](#) - Ohanapecosh Formation, rhyolite

### Bedrock Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

#### Qs - Surficial deposits (Holocene and Pleistocene)

Alluvium, mudflows, and glacial deposits; only large deposits shown.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

#### Qls - Landslides (Holocene and Pleistocene)

No additional description provided on the source map.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Qra - Volcanic rocks/Andesite of Mount Rainer (Holocene and Pleistocene)****Qra - Andesite of Mount Rainier volcano (Pleistocene and Recent)**

Chiefly hypersthene-augite andesite and minor olivine andesite in thick intracanyon lava flows and associated mudflows near base of volcano; thinner flows and interlayered breccia on upper slopes.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Qroa - Andesite of Mount Rainer, olivine andesite flows (Holocene and Pleistocene)**

Olivine andesite flows from Echo Rock and Observation Rock vents.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Qrp - Mount Rainier plugs and dikes (Pleistocene)**

Central plug of opalized andesite in Sunset Amphitheater; satellite plugs of olivine andesite at Echo Rock and Observation Rock; radial dikes.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tha - Andesite of Bee Flat (Pliocene?)**

Intracanyon lava flow of hypersthene-hornblende andesite.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tw - Welded tuff of The Palisades (Miocene or Pliocene)**

Pyroclastic rocks that grade downward into The Palisades plug.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tg - Granodiorite and quartz monzonite (Miocene or Pliocene)**

Subordinate amounts of quartz diorite, contact breccia, and fine-grained border rocks; central pluton and associated stocks.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tdi - Diorite, quartz diorite, granodiorite, and quartz monzonite porphyries (Miocene or Pliocene)**

Subordinate amount of microgranite, porphyritic granophyre, and felsite. Swarms of sills, dikes, and irregular small intrusive bodies clustered mainly near borders of the Tatoosh pluton and associated stocks. Includes unmapped septa of older rocks. Numerous poorly exposed sills and dikes not shown, especially in valleys of Panther, Laughingwater, and Chenius Creeks. Some small bodies shown schematically; sills with blunt ends extend for an unknown distance along strike.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Td - Diabase and basalt (Oligocene or Miocene)**

Chiefly in dikes and sill swarms. The Box Canyon sill complex along Cowlitz River contains unmapped septa of Ohanapecosh rocks.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tf - Fifes Peak Formation (Oligocene or Miocene)**

Basalt, basaltic andesite, and andesite flows; minor rhyolite flows, ash flows, and tuff breccia, volcanic sandstone, and volcanic siltstone of epiclastic and pyroclastic origin.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Ts - Stevens Ridge Formation (Oligocene or Miocene)**

Rhyodacitic ash flows; subordinate amounts of volcanic breccia, sandstone, and siltstone of epiclastic and pyroclastic origin.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tar - Basaltic andesite and rhyolite (Eocene)**

Plugs of massive and brecciated basaltic andesite which supplied lavas and fragmental material to the Ohanapecosh Formation. South Cowlitz Chimney is a flow-banded rhyolite plug.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**To - Ohanapecosh Formation (Eocene)**

Volcanic breccia, sandstone, and siltstone of epiclastic and pyroclastic origin.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tol - Ohanapecosh Formation, accumulations of basaltic andesite flows and coarse mudflows (Eocene)**

No description provided.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

**Tor - Ohanapecosh Formation, rhyolite (Eocene)**

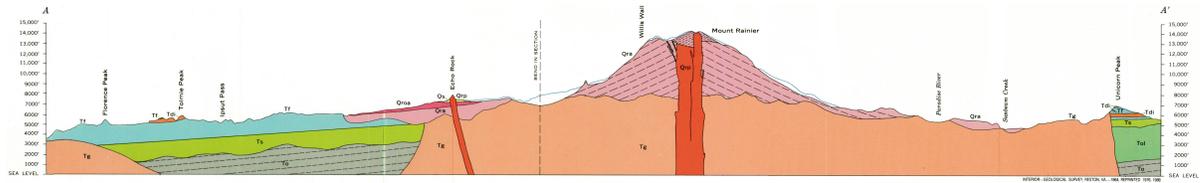
No description provided.

(GRI Source Map ID 2081) ([Geologic Map and Section of Mount Rainier National Park](#)).

## Geologic Cross Section

The geologic cross section present in the GRI digital geologic-GIS data produced for Mount Rainier National Park, Washington (MORA) is presented below. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

### Cross Section A-A'



Extracted from: ([Geologic Map and Section of Mount Rainier National Park](#)).

## GRI Digital Surficial Geologic Map of Mount Rainier National Park

### Surficial Map Units List

The surficial geologic units present in the digital geologic-GIS data produced for Mount Rainier National Park, Washington (MORA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qa - Alluvium). Units are generally listed from youngest to oldest. No descriptions for water or ice are provided. Information about each map unit is also presented in the Geologic Unit Information (MORAUNIT) table included with the GRI geology-GIS data.

### Cenozoic Era

#### Quaternary Period

[Qav](#) - Avalanche deposits of rock debris from Little Tahoma Peak

[Qa](#) - Alluvium

[Qac](#) - Alluvial cones

[Qtr](#) - Travertine

[Qly](#) - Landslide deposits, younger

[Ql](#) - Landslide deposits

[Qt](#) - Taluses

[Qbf](#) - Block-field deposits

[Qmf](#) - Mudflows

[Qg](#) - Garda Drift

[Qgy](#) - Garda Drift, younger

[Qgo](#) - Garda Drift, older

[Qbb](#) - Bomb-bearing deposits in South Puyallup River valley

[Qb](#) - Burroughs Mountain Drift

[Qf](#) - Interbedded mudflows and alluvium, units undifferentiated

[Qfd](#) - Interbedded mudflows and alluvium, unit D

[Qfc](#) - Interbedded mudflows and alluvium, unit C

[Qfb](#) - Interbedded mudflows and alluvium, unit B

[Qfa](#) - Interbedded mudflows and alluvium, unit A

[Qo](#) - Osceola Mudflow

[Qp](#) - Mudflow at Paradise Peak

[Qra](#) - Volcanic rocks/Andesite of Mount Rainier

[Qpt](#) - Protalus ramparts

[Qm](#) - McNeely Drift

[Qr](#) - Rock glacier deposits

[Qv](#) - Mudflow of Van Trump Park

[Qe](#) - Evans Creek Drift

[Qh](#) - Hayden Creek Drift

[Qod](#) - Old drift

#### Tertiary Period

[Tbr](#) - Rock formations older than Mount Rainier

## Surficial Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

### **Qav - Avalanche deposits of rock debris from Little Tahoma Peak (Holocene)**

Seven or more rockfalls from the steep north face of Little Tahoma Peak in December 1963 resulted in a series of large avalanches that rushed as far as 4.3 miles down valley. Although these avalanches were a form of landslide, they differed from most other landslides of the park in their speed. An extremely high velocity, probably exceeding 100 miles per hour, is indicated by the height to which some avalanches rose onto the sides of obstacles in their paths.

Such a velocity is also suggested by the way some avalanches caromed from one side of the valley to the other during movement, by their distance of movement, and by the presence of rock fragments embedded in the trunks of trees along the south margin of the avalanches a quarter of a mile up-valley from White River campground.

The avalanche deposits are jumbled mixtures of angular rock debris of many sizes in a loose reddish-gray matrix of sand ([fig. 19](#)). Scattered blocks of andesite breccia in the deposits are as large as 60 by 130 by 160 feet. The surface of the avalanche deposits is hummocky in most areas, but in some places there are ridges and furrows in the debris. Some ridges and furrows parallel the trend of the valley, and others are transverse to it. The deposits have a maximum thickness of about 100 feet, and they originally covered an area of about 2 square miles, including the part on the surface of Emmons Glacier. The total volume is estimated to be at least 14 million cubic yards.

The long distance some avalanches moved is attributed to the development of cushions of compressed air beneath the avalanches as they hurtled off the steep front of Emmons Glacier. These air cushions buoyed up the swiftly moving avalanches for long distances and prevented them from striking the ground.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qa - Alluvium (Holocene)**

Alluvium includes both unvegetated sand and pebble-to-boulder gravel deposited by modern streams and rivers and the same type material underlying forested terraces or benches as much as 15 feet higher than the stream channels. Some low terraces contain poorly sorted bouldery deposits that may be mudflows or alluvium transported by floods. Near the ends of present glaciers, alluvium locally includes lenticular mudflows a few feet thick that came from moraines or from rock debris on the glaciers; boulders larger than 5 feet in diameter in the alluvium probably were carried by these mudflows. Nearly all the alluvium shown on the geologic map has been formed within the last 500 years.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qac - Alluvial cones (Holocene)**

Alluvial cones are steeply sloping, poorly sorted stream deposits of loose rock debris which lie beneath cliffs and are wedge shaped in ground plan ([fig. 18](#)). Their surfaces are scarred by one or more gullies, the sides of which are paralleled by low bouldery ridges 5—25 feet wide and 3—10 feet high. Some cones seem to consist chiefly of rock fragments larger than 6 inches in diameter, but others are rich in debris of sand and pebble sizes. Very large blocks lie on the surface of some cones. Alluvial cones are distinguished from taluses by less steep slopes, by a markedly decreasing slope toward the toe, and by stream-gullied surfaces. Most cones head at the mouths of steep rock-walled gullies and have been

formed by small streams and mudflows that descend the gullies during rainstorms. From Ricksecker Point, a typical alluvial cone can be seen on the opposite side of the Paradise River valley ([fig. 4](#), locality 30), and the West Side Road crosses one at the base of Mount Wow ([fig. 4](#), locality 31).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qtr - Travertine (Holocene)**

Travertine is a calcium carbonate mineral that has been deposited by the water of warm or hot springs. Deposits of yellowish-orange to white travertine of unknown thickness that underlie parts of a meadow at Longmire and a small area near Ohanapecosh campground have been formed by warm spring water that still issues from the ground at both localities. Pumice layer W is interbedded with the travertine near Ohanapecosh campground.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Ql - Landslide deposits (Holocene)**

In addition to Ql, the unit description provided below pertains to the following subunit:

#### **Qly - Landslide deposits, younger (Holocene)**

Landslides consist of chaotic mixtures of loose rock debris, or several very large blocks of rock, that have broken away from the bedrock and have moved downslope. They include those which seem to be inactive and those in which there was evidence of movement during the period of field study (1960—67). An example of an inactive slide is one that originated in west-dipping bedrock just north of Ohanapecosh campground ([fig. 4](#), locality 27). Cuts in this landslide along State Highway 143 expose a jumbled mixture more than 100 feet thick of rock fragments of many sizes in which some layers or zones have a plastic purplish-gray clay matrix. The surface of the slide deposit is hummocky, includes closed depressions, and is strewn with angular blocks as much as 15 feet across. Another inactive slide is crossed by the Mather Memorial Parkway (U.S. Highway 410) half a mile north of Cayuse Pass ([fig. 4](#), locality 28). The slide originated in west-sloping bedrock and descended into the valley of Klickitat Creek, where it now impounds Ghost Lake. Highway cuts through the slide deposit show a loose mixture of rock fragments of many sizes, some as large as 20 feet across.

An active landslide is slowly moving down the west slope of Backbone Ridge ([fig. 4](#), locality 29). It consists of a jumbled mass of sandstone and claystone, probably only about 25 feet thick. From 1962 to 1966 the slide moved at an average rate of about 6 inches per year.

An active slide on the west side of the Nisqually River valley west of Paradise Park involves lava flows from the volcano as well as the underlying bedrock. The slide block seems to be dropping eastward toward the center of the valley and rotating, so that the north side of the block is moving more than the south side. The slide is broken into several smaller blocks by cracks that parallel the 1,000-foot-long main crack at the slide's head. Photographs taken in 1912 show the fresh scarp at the head of the slide, so it evidently began to move at some earlier time. The slide can be seen from various viewpoints along the trail from the Paradise visitor center to Panorama Point.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### Qt - Taluses (Holocene)

Taluses are loose accumulations of coarse rock fragments that lie beneath cliffs ([fig. 10](#)). Their surfaces slope at angles ranging from about 30° to 35°. Rock fragments in a talus are generally fresh and angular and range in size from pieces a few inches across to blocks that are several tens of feet in maximum diameter. Some taluses have bulbous toes that suggest movement by flowage, perhaps caused by ice within the rock debris. Taluses that are wholly forested are not shown on the geologic map.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### Qbf - Block-field deposits (Holocene)

Block-field deposits consist of angular rock fragments that lie on both sloping and horizontal surfaces. The rock fragments are pried from the underlying solid rock formations by the repeated freezing and expansion of moisture in cracks. Some block fields resemble taluses in that they have slopes of as much as 35° but they differ in that they are not littered with very large blocks and do not have a cliff at their head. Downslope-trending bands of vegetated and unvegetated rock debris a few feet to a few tens of feet wide give some sloping block fields a distinctly striped appearance. Other fields end downslope in elongate lobes of rock debris a few feet to several tens of feet wide and 1—4 feet thick. The shape of these lobes suggests that they originated from flowage of the rock debris, perhaps caused by saturation from rain or melting snow. Block fields are not common where rock debris produced by frost action consists mostly of fragments smaller than 3 inches in diameter. Some block fields probably date from the last major glaciation, and others may be of more recent age.

Especially well developed and easily accessible block fields are crossed by the trail to the Mount Fremont fire lookout ([fig. 4](#), locality 26).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### Qmf - Mudflows (Holocene)

As many as five mudflows, each of which is from a few feet to several tens of feet thick, lie on low terraces, valley sides, and some ridgetops in and adjacent to the valleys of Tahoma Creek and the North and South Puyallup Rivers ([fig. 17](#)). All have been formed within the last 4,000 years, and one is only about 440 years old. The mudflows are unsorted mixtures of boulders of many sizes in a yellowish-orange matrix of sand, silt, and clay. One, exposed in road cuts at Round Pass ([fig. 4](#), locality 24), can be traced along a trail to Lake George to a height of about 350 feet vertically higher than the pass, which indicates that the Tahoma Creek valley temporarily must have had at least 1,000 feet of mud flowing in it. Remnants of the deposit on the sides of the South Puyallup River valley indicate a comparable thickness or depth there. At Indian Henry's Hunting Ground, on the divide between the Tahoma Creek and Kautz Creek valleys, the southwest margin of the mudflow forms an abrupt front about 17 feet high where it is crossed by the Wonderland Trail ([fig. 4](#), locality 25). The boundary there between the mudflow and the adjacent surface is conspicuous because pumice layer Y abruptly disappears as one passes from the older surface onto the mudflow.

The approximate maximum height of the deepest mud flows in the valleys west of the volcano, shown by a heavy dashed line on the geologic map, is reconstructed from the highest known remnants of the deposits; this line probably represents the height attained by a single mudflow that occurred about 2,800 years ago. Another mudflow temporarily reached almost as high on the valley sides about 600 years ago. It had enough volume to move 25 miles downvalley and to extend an additional 15 miles into the Puget Sound lowland. All the mudflows originated in avalanches of clay and altered rock from the west side of the volcano at Sunset Amphitheater ([frontispiece](#)).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qg - Garda Drift (Holocene)**

In addition to Qg, the unit description provided below pertains to the following subunits:

#### **Qgy - Garda Drift, younger (Holocene)**

#### **Qgo - Garda Drift, older (Holocene)**

Moraines formed since the eruption of pumice layer C are included in the Garda Drift ([fig. 14](#)); contemporaneous glacial melt-water deposits, however, are represented on the geologic map only as alluvium. The till consists of a gray unsorted mixture of pebbles, cobbles, and boulders in a silt and sand matrix and is unweathered. The presence or absence of pumice layer W divides Garda moraines into groups that are older or younger, respectively, than about 450 years. Trees growing on some Garda moraines are at least 750 years old. Moraines younger than layer W include stable, forested deposits decades or a few centuries old as well as subsiding masses of rock debris that still bury blocks of slowly melting ice. Younger Garda moraines are especially unstable on steep valley sides in areas from which glaciers have receded within the last half century. Boulders in the moraines become dislodged from time to time and roll and bound down to the valley floor at high speed. During periods of heavy rainfall or rapid snowmelt, saturated masses of drift sometimes move from the moraines onto the valley floors as mudflows.

Moraines of Garda Drift range in size from ridges only a few feet high and a few tens of feet wide to massive complex end moraines such as the one that was formed in the White River valley by Emmons Glacier between the 17th century and about 1910 ([fig. 15](#); [fig. 4](#), locality 21). Dates shown on individual moraines on the geologic map are based on the earliest growth ring of the oldest known living tree on the moraine; the moraine is older than the tree by an unknown number of years, perhaps as much as several decades. One of the most readily accessible Garda moraines in the park lies at the west end of the bridge across the Nisqually River ([fig. 4](#), locality 22), 3.5 miles northeast of Longmire. This moraine is conspicuous because trees on it are much younger and smaller than those in the adjacent older forest. When this moraine was formed in 1840, Nisqually Glacier covered the site of the present highway and reached to a point about 750 feet downvalley from the bridge.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qbb - Bomb-bearing deposits in South Puyallup River valley (Holocene)**

A deposit of unsorted and unstratified rock debris that contains many light-olive-gray breadcrust bombs is exposed along the highway in the South Puyallup River valley ([fig. 4](#), locality 23). Breadcrust bombs are formed when blobs of lava are thrown from a volcano; as the bomb cools, a solid skin forms, which then ruptures as gas pressure in the lava causes it to expand slightly. The bomb's exterior is a network of fissures and segments that resemble those on a loaf of hard-crust bread; inside, most bombs are very porous because of the gas bubbles that formed in the lava ([fig. 16](#)). Many bombs have one flat side, which was formed when still-plastic blobs of hot lava struck the ground after flying through the air. Bombs in the South Puyallup River valley are 6 inches to 4 feet in diameter.

The bombs are contained in a deposit of loose purplish gray sand. Although the bombs are the most conspicuous part of the deposit, fragments of dense glassy dark-gray andesite as much as several inches in diameter are also abundant. The deposit is at least 200 feet thick in places, and it overlies very coarse mudflows and alluvium in which no bombs were seen. On top of the deposit are two thin clayey mudflows which probably were formed about 1,000 and 600 years ago, respectively. A carbonized log 4 feet long that was found just above the base of the bomb-bearing deposit had a radiocarbon age of about

2,500 years. Streams have eroded the bomb-bearing deposit to form ridges that greatly resemble lateral moraines near the West Side Road.

The deposit originated when hot rock rubble, ash, and bombs avalanched from the top of the volcano during an eruption. Even though the rock debris flowed down the South Puyallup River valley in a fluid manner, the magnetic properties of rock fragments indicate temperatures of hundreds of degrees above the boiling point of water when movement stopped. Thus, the rock debris must have flowed in a dry condition, and it probably was "lubricated" by steam, hot air, and other gases.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qb - Burroughs Mountain Drift (Holocene)**

The Burroughs Mountain Drift was formed during a period of glacier expansion that occurred between about 2,500 and 3,000 years ago. Although the glaciers of the park became only a little larger than they are today, this was a significant change, for during the time since the end of the last major glaciation they had been smaller. Burroughs Mountain moraines can be recognized by the fact that they are older than pumice layer C ([fig. 14](#)), and younger than layer Y.

Till in the Burroughs Mountain moraines is gray, generally loose, and not appreciably weathered. The moraines below timberline are densely forested with trees several generations younger than the first forest that became established on the moraines after their formation. Most of the Burroughs Mountain moraines are only a few yards beyond moraines formed within the last 700 or 800 years, although those of Winthrop Glacier represent a glacier 300 feet thicker than at any subsequent time. The largest Burroughs Mountain moraines occur in the areas adjacent to Winthrop Glacier and between Winthrop and Carbon Glaciers, and smaller ones have been identified at a few other places in the park. The Wonderland Trail crosses a Burroughs Mountain moraine of Winthrop Glacier on the west slope of Burroughs Mountain ([fig. 4](#), locality 20).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qf - Interbedded mudflows and alluvium, units undifferentiated (Holocene)**

In addition to Qf, the unit description provided below pertains to the following subunits:

**Qfd - Interbedded mudflows and alluvium, unit D (Holocene)**

**Qfc - Interbedded mudflows and alluvium, unit C (Holocene)**

**Qfb - Interbedded mudflows and alluvium, unit B (Holocene)**

**Qfa - Interbedded mudflows and alluvium, unit A (Holocene)**

Mudflows are interbedded with alluvium in terraces or benches along the sides of nearly every major valley in the park. Individual mudflows are from about 1 to 15 feet thick and typically are unsorted mixtures of sand, clay, and stones of many sizes. Individual mudflows lack bedding, although a succession of several mudflows, or an alternation of mudflows and alluvium, may give an outcrop a layered appearance. Most mudflows are purplish gray where unweathered, and yellowish orange or yellowish brown where weathered. Many of these mudflows resulted from floods caused by eruptions. The volcano has repeatedly erupted hot rock debris and lava flows which melted snow and ice. The resulting floods that cascaded down the flanks of the cone became mudflows by scouring loose alluvium and moraines on the valley floors. Other mudflows, however, probably originated during periods of unusually heavy rainfall, when parts of recent moraines became saturated and slid and flowed downvalley.

Alluvium that is interlayered with the mudflows was formed mainly by streams and rivers like those of today. It generally consists of sand and gravel in which some boulders are as large as 6 feet in maximum diameter, and it ranges in thickness from a few inches to at least 50 feet. Alluvium can be distinguished from mudflows mainly by the presence of bedding and by lenses and layers of well-sorted material.

Pumice layers that locally lie between deposits of alluvium and mudflows are commonly interbedded with rooted stumps, logs, and other organic matter formed on forest floors that have since been buried. As many as four successive buried forest layers can be seen in the steep banks of Kautz Creek near the Wonderland Trail ([fig. 4](#), locality 18), and the north bank of Tahoma Creek shows a similar sequence about a mile upstream from Tahoma Creek campground ([fig. 4](#), locality 19). Some pumice layers, whose age is known, permit age bracketing of interbedded deposits, and the presence or absence of other layers on top of the deposits permits subdivision of the mudflows and alluvium into map units of four ages. (See explanation for the geologic map.) Unit A includes deposits older than pumice layer O; unit B contains the deposits younger than layer O and older than layer Y; unit C represents the deposits younger than layer Y but older than layer W; and unit D includes the deposits younger than layer W. The surface deposit represented on the map commonly is underlain by mudflows and alluvium of older units.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qo - Osceola Mudflow (Holocene)**

The Osceola Mudflow is the largest mudflow that has originated at Mount Rainier and is one of the largest volcanic mudflows in the world. It originally covered an area of more than 100 square miles in the Cascade Range and the Puget Sound lowland, and its volume probably was more than half a cubic mile. Radiocarbon determinations of logs in the mudflow indicate an age of about 5,700 years.

The mudflow is an unsorted mixture of plastic clay, sand, and rock debris that includes boulders as large as 15 feet in diameter ([fig. 13](#)). It is purplish gray when fresh and weathers to yellowish orange. Remnants of the mudflow high on the sides of the White River and West Fork valleys show that both valleys were temporarily filled with streams of mud more than 500 feet deep. After the crest of the mudflow passed a given point, most of the material drained away downvalley, leaving veneers a few feet to a few tens of feet thick on the valley walls. Much of the flowing mud finally came to rest in the Puget Sound lowland, 40–70 miles away.

The presence of the Osceola Mudflow on ridgetops above Glacier Basin and at the top of Steamboat Prow indicates that it originated even higher on the volcano. This distribution and a large clay content suggest that the mudflow was caused by huge slides of altered rock material from a former summit of the volcano. These slides probably were triggered by volcanic explosions, and they produced the large crater-like depression at the top of the volcano that contains the present summit lava cone.

Roadcuts expose the mudflow at the White River Ranger Station ([fig. 4](#), locality 16), and one of the best outcrops is in the valley of Inter Fork about 1.5 miles west of White River campground ([fig. 13](#); [fig. 4](#), locality 17).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qp - Mudflow at Paradise Peak (Holocene)**

A very large landslide of clayey altered rock avalanched down the south side of Mount Rainier between 5,800 and 6,600 years ago. Upon reaching the lower slopes of the volcano, the avalanche became a mudflow that spread over the Paradise area. Here the mudflow deposited a plastic yellowish-orange

mixture of unsorted clay, sand, and rock fragments a few inches to more than 15 feet thick. Blocks in the deposit are as large as 6 feet in diameter. The presence of thin remnants on top of Mazama Ridge indicates that the mudflow must have been 600 feet deep in the adjacent Paradise River valley. Farther downvalley, at Ricksecker Point, the mudflow was temporarily at least 800 feet deep. The mudflow lies on top of pumice layer O ([fig. 12](#)).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

## **Qra - Volcanic rocks/Andesite of Mount Rainer (Holocene and Pleistocene)**

### **Qra - Volcanic rocks of Mount Rainier (Pleistocene)**

No additional description provided on the source map.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

## **Qpt - Protalus ramparts (Pleistocene)**

Protalus ramparts are ridges of loose angular rock fragments that lie a few tens of feet beyond the toes of taluses ([fig. 11](#)). Blocks larger than 3 feet in diameter are rare, and most ramparts seem to consist chiefly of fragments 6 inches to 2 feet in diameter. The ridges are generally 10—30 feet wide and 5—15 feet high on the side next to the talus. In ground plan they range from straight to sinuous; many are arcuate and are convex in a direction away from the talus. Their distribution, shape, and nearness to taluses indicate that they were formed at some time when thick persistent snowbanks buried the toes of some cliffs and parts of taluses. Rock debris falling from a cliff and sliding down the snowbank accumulated at the toe of the snowbank as a ridge or rampart; a subsequent change in climatic conditions prevented such a large snowbank from forming, so that the falling rock debris then became part of the main talus and building of the rampart ceased.

Most protalus ramparts are the same age as the McNeeley Drift. The close association of protalus ramparts with McNeeley moraines in some cirques suggests that the glacier responsible for the moraine dwindled until only a perennial snowbank remained, at the toe of which the rampart was formed.

The trail to White River Park crosses a typical and readily accessible protalus rampart at the base of Sunrise Ridge ([fig. 4](#), locality 14), and there are several other ramparts associated with McNeeley moraines along the north side of Sunrise Ridge a little to the west.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

## **Qm - McNeely Drift (Pleistocene)**

McNeeley Drift, named in this report, consists of till in moraines formed during the latest part of the most recent major glaciation, probably about 11,000 years ago. The name of the drift is taken from McNeeley Peak, which is north of Yakima Park. A typical moraine lies within a north-facing cirque half a mile south of the peak ([fig. 4](#), locality 9). Weathering extends to a depth of 15 inches or less in the till, and stones in the till that have been decomposed by weathering processes are rare. McNeeley moraines are found adjacent to some large active valley glaciers on Mount Rainier and in some cirques at altitudes between 5,500 and 6,700 feet. Areas in front of cirque moraines generally consist of either glacier-scoured bedrock or feature less Evans Creek Drift. McNeeley moraines are sharp crested and little modified by erosion. They range from single low narrow ridges of till to accumulations as much as 1,000 feet wide that are distinguished by multiple ridges. One of the largest McNeeley moraines dams Mystic Lake on the north side of the park, and the Wonderland Trail crosses another at the south end of Berkeley Park ([fig. 4](#), locality 10). A small McNeeley cirque moraine can be seen along the highway between Tipsoo

Lake and Chinook Pass ([fig. 4](#), locality 11).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qr - Rock glacier deposits (Pleistocene)**

Rock-glacier deposits are thick flat-lying or gently sloping accumulations of coarse angular rock debris that have a lobate form and a surface marked by pits and by ridges and furrows. Angular blocks several tens of feet in maximum dimension are generally strewn over the surface. A depression separates the upslope margin of most rock-glacier deposits from nearby talus ([fig. 10](#)). The fronts of rock glacier deposits are abrupt, steep, and from 25 to 100 feet high. Rock-glacier deposits owe their shape and size to flowage of accumulations of rock debris that contain ice. Active rock glaciers differ from true glaciers chiefly in having a very high proportion of rock debris to ice. All of those in the park were formed during a late part of the most recent major glaciation and are inactive now.

Most rock-glacier deposits occupy north- or east-facing cirques within an altitude range of 5,500 to 6,600 feet. Many are closely associated with McNeeley Drift, and in some cirques they merge with McNeeley moraines. All are about the same age as the McNeeley Drift.

A trail just east of Mount Fremont crosses a representative rock-glacier deposit ([fig. 4](#), locality 12), and one of the largest in the park occupies an east-facing cirque between the Palisades and Hidden Lake ([fig. 10](#); [fig. 4](#), locality 13).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qv - Mudflow of Van Trump Park (Pleistocene)**

Trump Creek northeast of Comet Falls. The mudflow is widespread in areas beyond an end moraine of Van Trump Glacier that probably was formed about 11,000 years ago, but it does not overlie the moraine itself and thus is older.

Between 11,000 and 15,000 years ago a large landslide of rock from the summit of Mount Rainier swept down the south flank of the volcano and spread as a mudflow over Van Trump Park. There it deposited a yellowish-orange unsorted mixture of clay, sand, and rock debris which is as much as 6 feet thick on the ridgetop at Van Trump Park ([fig. 4](#), locality 8) and is 20 feet thick in the valley of Van Trump Creek northeast of Comet Falls. The mudflow is widespread in areas beyond an end moraine of Van Trump Glacier that probably was formed about 11,000 years ago, but it does not overlie the moraine itself and thus is older.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qe - Evans Creek Drift (Pleistocene)**

Between about 25,000 and 15,000 years ago Mount Rainier and the adjacent mountains were again buried by large glaciers; these glaciers formed the Evans Creek Drift, which consists of till as well as stream-deposited sand and gravel. These glaciers developed during an early part of the last major glaciation of the Pleistocene (Ice Age); at that time lateral moraines were deposited along the margins of glaciers high on the sides of some valleys and even along the crests of some divides, as at Ricksecker Point ([fig. 4](#), locality 6) and Rampart Ridge. Till in the moraines is generally very coarse, loose or slightly compacted, and as much as 50 feet thick. The till is mostly gray or purplish gray, but it has a yellowish-brown oxidized zone in the upper 2 or 3 feet that has been formed by weathering processes since the till was deposited. Stones in this oxidized zone rarely have weathered rinds. Evans Creek till is especially

well exposed in roadcuts along the north side of the White River valley east of Yakima Park ([fig. 4](#), locality 7).

At the time the Evans Creek Drift was deposited, ice fields and glaciers mantled the slopes of the volcano above an altitude of about 5,000 feet. Each major valley was occupied by a glacier 1,000—1,500 feet thick which extended from 5—35 miles beyond the park boundaries ([fig. 9](#)).

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qh - Hayden Creek Drift (Pleistocene)**

The Hayden Creek Drift is here named for a stony till that is intermittently exposed in cuts along the Mowich Lake Road ([fig. 7](#)) from a point near the mouth of Hayden Creek ([fig. 4](#), locality 4) westward beyond the park boundary.

The distribution of Hayden Creek Drift outside the park, as well as the drift's presence on some high ridges within the park, indicates deposition during a glaciation of icecap proportions, when glaciers west of Mount Rainier locally reached the western front of the Cascade Range. The entire park was covered by ice at that time. The Hayden Creek Drift probably was formed during a glacial episode that occurred between 35,000 and 50,000 years ago.

Extensive weathering in the Hayden Creek Drift shows it to be older than the Evans Creek Drift (described next), which was formed during the most recent major glaciation. Although initially brownish gray, the Hayden Creek till has been weathered to dark yellowish brown to a depth of 6—8 feet below the ground surface. Stones in the upper few feet of the till have been partly decomposed; these stones have weathered rinds or shells 1—3 mm thick ([fig. 8](#)). Hayden Creek Drift was found at the summits of Iron and Copper Mountains and at the top of a ridge that extends eastward from Tyee Peak. A brown bouldery till at least 100 feet thick on a ridge northwest of The Palisades probably is also Hayden Creek Drift.

Hayden Creek Drift underlies a thick deposit of Mount Rainier pumice on the north valley wall of the White River about 2 miles southeast of Yakima Park ([fig. 4](#), locality 5). The pumice can be seen in a roadcut a short distance west of Yakima Creek where it is overlain by an old talus deposit and Evans Creek till. Wood in the pumice is more than 38,000 years old, as determined by radiocarbon dating. More than 50 feet of Hayden Creek till is exposed beneath the pumice in a steep bank downslope from the highway.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

### **Qod - Old drift (Pleistocene)**

The age and extent of the glaciers responsible for the old drift are not known, but glaciers evidently covered this part of the Cascade Range very early in the development of Mount Rainier, perhaps even before the volcano first appeared. The old drift consists mostly of glacial deposits over lying bedrock formations that are older than Mount Rainier and underlying lava flows from the volcano. The lava flows are of a rock known as andesite,<sup>1</sup> and they form many of the ridges that radiate from the base of the volcano, such as Mazama and Rampart Ridges and Burroughs Mountain. Each old drift deposit shown on the geologic map contains compact till, but some also include mudflows and rubbles of volcanic origin.

Old drift exposed in a roadcut upslope from Narada Falls lies on a surface of glacially smoothed and scratched bedrock ([fig. 4](#), locality 1). The till at this locality is overlain by a pumice-bearing deposit of

sand and fine gravel that is interbedded with mudflows. This deposit, together with the till, is about 100 feet thick and is overlain by a lava flow from Mount Rainier that forms Mazama Ridge.

Old drift at the west end of Burroughs Mountain ([fig. 4](#), locality 2) consists of about 800 feet of compact bouldery gray till and beds of sand and fine gravel. It is overlain, consecutively, by a deposit of loose gray and red volcanic rubble about 300 feet thick and by a lava flow from Mount Rainier. In Glacier Basin ([fig. 4](#), locality 3) old till lies on top of compact mudflows and hard bedrock ([fig. 5](#)). The till is very compact and bouldery ([fig. 6](#)) and is several hundred feet thick. Banked against it is an old lava flow from Mount Rainier, and both the till and the flow are overlain, in turn, by a red volcanic rubble and a younger lava flow from Mount Rainier. The red rubble probably is part of the deposit that overlies the old drift at the west end of Burroughs Mountain. The old mudflows, the till, and the red rubble have been intruded by a wall-like andesite dike that forms a prominent ridge along the north side of Glacier Basin.

**Footnote**

<sup>1</sup>Rock formations in Mount Rainier National Park are described in some of the reports listed at the end of the text.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#))

**Tbr - Rock formations older than Mount Rainier (Eocene to Miocene or Pliocene)**

Undifferentiated volcanic, sedimentary and intrusive igneous rocks.

(GRI Source Map ID 2077) ([Surficial Geology of Mount Rainier National Park](#)).

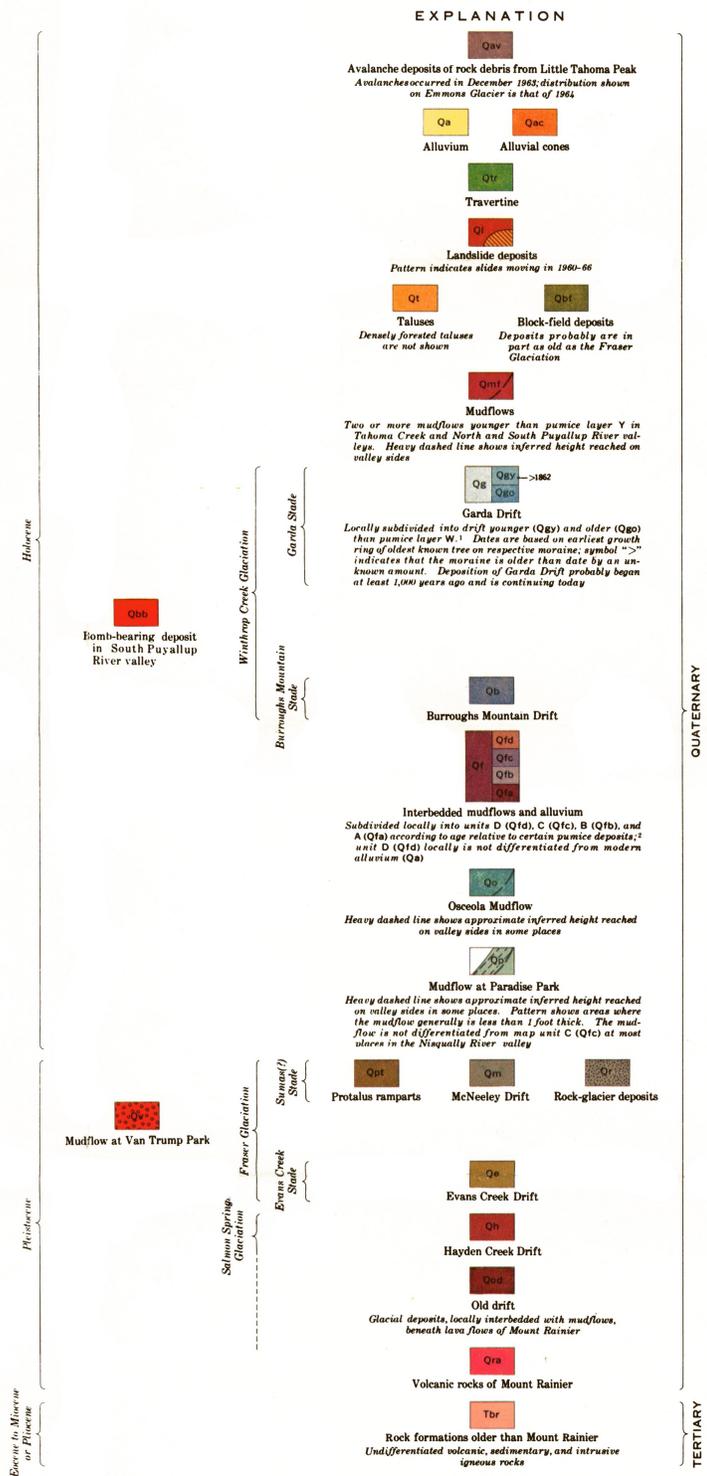
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## **GRI Source Map Ancillary Information**

### **Geologic Map and Section of Mount Rainier National Park (I-432)**

Fiske, R.S., Hopson, C.A., and Waters, A.C., 1964, Geologic Map and Section of Mount Rainier National Park, Washington: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-432, scale 1:62,500 (*GRI Source Map ID 2081*).

### I-432 Correlation



Extracted from: [\(Geologic Map and Section of Mount Rainier National Park\)](#).

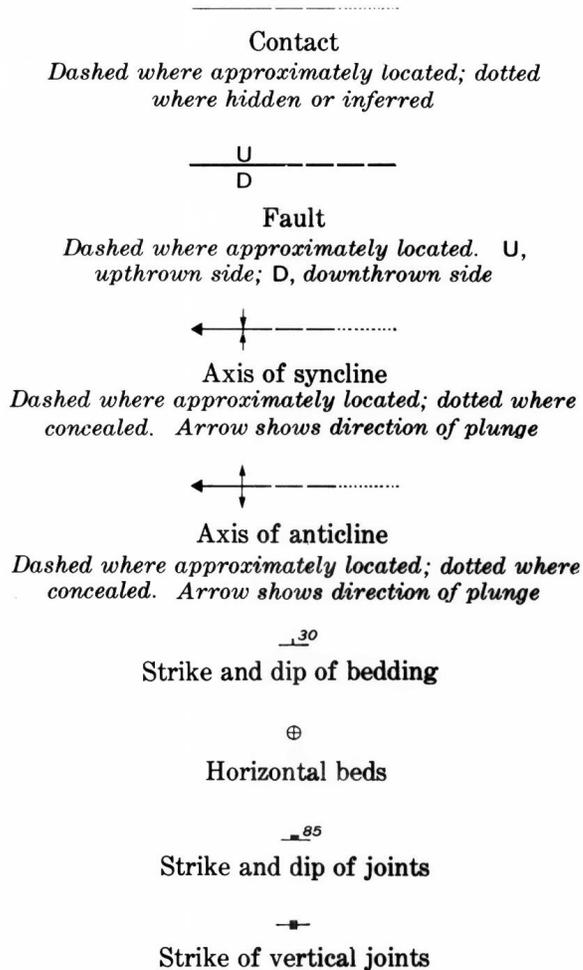
## I-432 Index Map



INDEX MAP OF WASHINGTON  
SHOWING LOCATION OF  
MT RAINIER NATIONAL  
PARK

*Extracted from:* ([Geologic Map and Section of Mount Rainier National Park](#)).

## I-432 Map Legend



NOTE: Glacial outline as shown by dashed blue line was mapped by author in 1959

Extracted from: ([Geologic Map and Section of Mount Rainier National Park](#)).

## I-432 Report

### Introduction

Majestic Mount Rainier dominates the Cascade Mountains in south-central Washington. The mountain, named Ta-co-man "snow-covered mountain" by the original Indian inhabitants of the Puget Sound country, towers 8000 feet above the peaks at its foot and 14,410 feet above the sea. Moreover, it is the highest and most imposing member of the long line of Quaternary volcanoes that surmounts the Cascades from the Canadian border to northern California.

An exceedingly interesting geologic history lies behind this impressive scenery. This history tells of the birth and growth of the volcano that built Mount Rainier. It also goes back much further in time and tells of ancient volcanoes, now largely obliterated by erosion that erupted enormous amounts of volcanic debris upon everchanging landscapes that were quite different from the one we know today.

This history is described in part by this text and in part by the colored geologic map and section printed on the other side of this sheet. The colors on the geologic map distinguish the sixteen different rock units found in the park. In many places these rocks are covered by a thin veneer of vegetation, soil, or other unconsolidated debris, but by studying the available outcrops, we have been able to infer the probable distribution of the various rock units beneath this surficial cover. The geologic section shows the inferred configuration of the rocks at depth along the line A-A', running northwestward across the park. A more complete description of the geology of the park may be found in Professional Paper 444 of the U.S. Geological Survey, published in 1963, and entitled "Geology of Mount Rainier National Park, Washington."

### General Statement

All the rocks exposed within Mount Rainier National Park are quite young when compared with the total life span of the earth. It is generally believed by geologists that the earth was formed more than 4000 million years ago, but the rocks in the park were formed only within the past 60 million years, during the Tertiary and Quaternary Periods. By the beginning of the Tertiary Period, dinosaurs were extinct and the primitive ancestors of many of today's familiar mammals roamed the earth. The trees and other plants that grew in the early Tertiary forests were clearly the forerunners of the present-day vegetation. Despite the relative youth of its rocks, however, the area we know as Mount Rainier National Park has had an extremely eventful geologic history crowded into this "brief" period of 60 million years.

This history is recorded in the various kinds of rock exposed in the park. These rocks fall naturally into three main groups: (1) bedded rocks of Eocene, Oligocene, and Miocene age; (2) granitic intrusive rocks of Miocene and Pliocene age; and (3) lava flows and related rocks of Mount Rainier volcano, of Quaternary age.

### Bedded Rocks of Eocene, Oligocene, and Miocene Age

Countless eruptions from many widespread volcanoes produced the bedded rocks of Eocene, Oligocene, and Miocene age, and the total volume of this material dwarfs the relatively small amount of lava that later built Mount Rainier. The cone-shaped pile of lava that forms Mount Rainier lies almost entirely within the area of the park. The older deposits, in contrast, originally formed a vast field of volcanic rocks more than 15,000 feet thick that extended far beyond the confines of the park. Later erosion has removed much of this huge volcanic field, but within its remnants, we are able to recognize three geologic formations that were the products of three main periods of volcanism. These formations have been named Ohanapecosh, Stevens Ridge, and Fifes Peak.

**Ohanapecosh Formation** — During Eocene time the area we know as Mount Rainier National Park

was part of a broad, low-lying coastal region that extended along the site of the present Cascade Mountains. Much of this lowland was submerged beneath large lakes or embayments of the sea, and clusters of highly explosive volcanoes dotted the region. Immense volumes of fragmental volcanic debris and lesser amounts of lava were erupted from these volcanoes, and these materials built up the thick and complex pile of volcanic rocks known as the Ohanapecosh Formation.

Some of the Ohanapecosh volcanoes grew on land near large bodies of water. They were unpredictable volcanoes—sometimes erupting floods of andesite lava, at other times exploding violently and blasting large volumes of volcanic debris high into the air. This debris fell over wide areas, and much of it was swept by rainwash and rivers into the nearby lakes and bays.

Other Ohanapecosh volcanoes grew at the bottom of the lakes and bays. These underwater volcanoes were repeatedly racked by violent explosions, and they disgorged most of the huge volume of shattered volcanic debris that is the particular hallmark of the Ohanapecosh Formation. The water relentlessly worked its way down the smoldering threats of these volcanoes and produced countless steam-blast explosions. These may have helped to trigger the larger eruptions that tore the insides from some volcanoes and blasted the entire tops from others. Liquid lava emerging under water chilled so rapidly that it, too, shattered into pieces, adding to the vast amounts of fragmental debris.

This freshly erupted debris was heaped on the upper flanks of the active underwater volcanoes, where, from time to time, large volumes of it slid away and flowed downslope along the bottom into deeper water. These repeated surges deposited layer upon layer of volcanic debris which accumulated to thicknesses of 8000 or 10,000 feet throughout much of the area (map symbol: [To](#)). Hundreds of such layers can be seen in the highway roadcuts on the east side of Backbone Ridge, and thousands more are exposed in outcrops scattered throughout the eastern third of the park.

After the volcanic activity subsided the newly-deposited Ohanapecosh Formation was compressed into broad folds, and most of the original minerals and other volcanic debris were replaced by zeolites and other new minerals. These new minerals firmly cemented the fragmental debris into hard rocks and imparted the dark gray and green colors that are so typical of the Ohanapecosh deposits. The entire area was then uplifted, and streams and rivers carved a hilly terrain with valleys as deep as 1500 feet into the rocks of the Ohanapecosh Formation.

**Stevens Ridge Formation** —The rocks of the Stevens Ridge Formation (map symbol: [Ts](#)) were deposited directly upon this hilly terrain during Oligocene or Miocene time. The earliest eruptions from the Stevens Ridge volcanoes showered thin layers of pumice and ash over the area. Many trees growing on this land surface survived the first thin ash falls, but their stubborn resistance to the volcanic activity soon proved to be futile.

In the most catastrophic event ever to befall the area, a series of searing hot ash flows descended upon and smothered the former landscape. These ash flows consisted of swirling mixtures of volcanic dust, bits of pumice, and other freshly erupted material buoyed up and greatly mobilized by hot volcanic gases. Well lubricated by the expanding gases, some of the flows probably achieved velocities of 60 or 80 miles per hour as they raced downslope from their volcanic vents. The first ash flows swept violently into the valleys, overwhelming streams, churning into the soil, and engulfing trees that stood in their path. Later ash flows overrode their predecessors and quickly built up deposits hundreds of feet thick which completely drowned the pre-existing hills. After the ash flows came to rest many of them retained sufficient heat to keep the small bits of volcanic glass and fragments of pumice soft enough to compact and weld together, producing the rock known as welded tuff.

Most of the Stevens Ridge ash flows have been eroded from the area of the park, but a few conspicuous remnants have survived. The prominent ledge capping the western side of Backbone Ridge is a remnant of the thick basal ash flow of the Stevens Ridge Formation. Some pieces of wood, bits of soil, and other

debris churned into the lower part of this ash flow can easily be seen in highway roadcuts near the top of the ridge. The same ash flow can be traced northwestward to the lower slopes of Stevens Ridge, where it is well exposed in roadcuts of the Stevens Canyon highway. The cliffs on the southern slope of Stevens Ridge provide some of the best exposures of the Stevens Ridge Formation in the park. Here, as elsewhere, the formation consists chiefly of ash flows which are overlain by thin deposits of volcanic particles transported and deposited by small streams and rivers.

No remnants of the volcanoes that erupted the ash flows and other material in the Stevens Ridge Formation have been found within the park. Large ash flows are known to travel many miles before coming to rest, thus the remains of the Stevens Ridge volcanoes may lie far beyond the boundaries of the park.

**Fifes Peak Formation** —The andesite and basalt lava of the Fifes Peak Formation (map symbol: [If](#)) was erupted directly on top of the Stevens Ridge Formation during Oligocene or Miocene time. Instead of exploding into bits of ash and pumice the lava emerged in sticky streams that built low, overlapping volcanic cones. Gradually, an extensive field of interfingering lava flows was built up and attained a thickness of at least 2400 feet. Only small remnants of this lava field have survived erosion within the park; the largest underlies much of the rugged area near Mowich Lake northwest of Mount Rainier. The only remnant of Fifes Peak lava preserved in the southern part of the park caps the very top of Unicorn Peak.

The Fifes Peak volcanoes have been so extensively dissected by erosion that it is doubtful whether any remnants of them have survived in the park. This erosion, however, could not destroy the many feeders that supplied lava to these volcanoes, and four major swarms of them have been mapped (map symbol: [Id](#)). These feeders now appear as dikes of lava which rose and solidified within nearly vertical fissures cutting the older rocks. The dikes range in thickness from 6 inches to about 20 feet, and many can be traced for about a mile along the surface of the ground. The largest swarm of dikes cuts the rocks of the Ohanapecosh and Stevens Ridge Formations on Backbone Ridge; smaller swarms appear on the Stevens Peak, Mount Wow, and in the headwaters of the North Fork of the Puyallup River. Clusters of Fifes Peak volcanoes probably grew above each of these dike swarms, but they have now been completely eroded away.

Large volumes of Fifes Peak lava were forcefully injected underground between the strata of the Ohanapecosh and Stevens Ridge Formations, and slowly cooled to form tabular rock masses called sills. The thickest and most extensive sills underlie the low country along the Muddy Fork of the Cowlitz River; the Box Canyon of the Cowlitz slices into one of these thick sills. Smaller sills related to the Fifes Peak Formation are exposed near Longmire.

As the eruptions of Fifes Peak lava waned the area was again compressed, and the folds initially formed after deposition of the Ohanapecosh Formation were further accentuated. Great fractures, called faults, formed as rocks of the Ohanapecosh, Stevens Ridge, and Fifes Peak Formations broke and shifted in position to relieve the stresses. The base of the Stevens Ridge Formation on Stevens Peak lies about 3000 feet higher than it does in the valley of Stevens Canyon as a result of vertical movement on the Stevens Peak fault. During this period of folding and faulting, the stage was set for the second major episode in the geologic history of the park—invasion by the Tatoosh pluton.

### **Tatoosh Pluton and Associated Intrusives**

Another great upward surge of molten rock in Miocene and Pliocene time heralded the rise of the Tatoosh pluton. But instead of rising to the surface and erupting as normal lava, most of this molten material stopped short of the surface and invaded the rocks of the Ohanapecosh, Stevens Ridge, and Fifes Peak Formations. Molten rock that remains underground is called magma, and when large volumes of magma accumulate and solidify at depth, intrusive igneous bodies or plutons are formed. The top of a

large and complex granitic pluton (map symbol: [Tg](#)) has been exposed throughout much of the park where deep canyons and cirques have carved through its roof of older rocks.

The first pulses of magma that fed the Tatoosh pluton were not large but were so numerous that in places, they riddled the older formations with small intrusive bodies (map symbol: [Tdi](#)). The magma worked its way upward through hundreds of narrow dikes that cut the strata of the Ohanapecosh Formation. When lateral zones of weakness were encountered, the magma was injected outward between the rock strata in extensive sheet-like masses which solidified to form sills.

As the tempo of intrusion increased, new fissures opened as rapidly as the magma in adjacent ones congealed, and sills were injected in great profusion. Some new sills spread out along the upper or lower edges of older ones, so that two, three, or even a dozen sills built up in single chambers. In some areas, later dikes sharply crosscut the earlier dikes and sills, producing complex boxworks of intersecting intrusive bodies. Some of the sills and dikes are large enough to be outlined on the geologic map, although hundreds of others are much too small to be shown.

Where the magma worked its way up to the top of the Ohanapecosh Formation it encountered a pronounced zone of weakness along the base of the overlying Stevens Ridge Formation, and hundreds of thick sills spread laterally into this zone. Skyscraper Mountain and the area to the north is underlain by a stack of such sills nearly 2000 feet thick. Some dikes and sills intruded to even higher levels, invading the rocks of the Stevens Ridge and Fifes Peak Formations.

This maze of dikes and sills, however, was only the forerunner of the main phase of the Tatoosh pluton. The huge magma reservoir that was feeding the sills and dikes gradually worked its way upward, lifting up large masses of the Ohanapecosh Formation that resisted its rise. Much of the magma broke upward through the Ohanapecosh Formation and invaded the Stevens Ridge and Fifes Peak Formations, stopping just short of the surface of the ground. At several places the upward surges could not be contained, and the magma broke through to the surface with explosive violence. Most of the material erupted onto the surface has now been eroded from the park; the thick mass of welded tuff at The Palisades (map symbol: [Tw](#)) is the only surviving remnant.

The remainder of Pliocene time was chiefly a period of uplift and erosion in the park, although igneous activity such as eruption of the lava flow at Bee Flat (map symbol: [Tha](#)) may have continued sporadically. Long after the Tatoosh magma had cooled and solidified, the thin roof of older rocks covering the pluton was partly eroded away, and the coarse-grained rock in the massive core of the pluton was laid bare throughout much of the park. Some of the best exposures of this rock can be seen in the rugged cirques and peaks of the Tatoosh Range, from which the pluton takes its name. North of the Tatoosh Range, the pluton broadens and disappears beneath the lavas of Mount Rainier, but it reappears on the north side of the mountain in the headwaters of the Carbon and White Rivers. Thus, the eroded core of the Tatoosh pluton evidently extends completely beneath Mount Rainier and forms the rugged platform upon which the volcano grew.

### **Mount Rainier Volcano**

The andesite lava that built Mount Rainier (map symbol: [Qra](#)) first broke through to the surface in Pleistocene time and flooded the rugged terrain carved in the older rocks. Some of the early flows traveled 15 miles from the young volcano and filled the ancient canyons to depths of 2000 feet, forming enormous intracanyon lava flows.

The oldest intracanyon flows now form ridge crests or flat benches hanging far above the floors of the present-day canyons. These flows originally filled the valleys in the area, but vigorous erosion by rivers and glaciers was renewed when the lava congealed and has proceeded relentlessly ever since. Thus, many of the river canyons of today have been cut far below the floors of the old filled canyons.

A good example, readily seen by visitors to the park, is the large intracanyon flow whose remnants underlie Burroughs Mountain and the flat surface of Yakima Park. This stream of lava poured about 7 miles down the canyon of the ancestral White River, and its blunt end is now marked by the tiers of thin lava columns, resembling stacked cordwood, exposed in the highway roadcuts below Sunrise Ridge. The ancestral White River was displaced to the south side of the intracanyon flow, where it proceeded to cut the present-day canyon. The flow has been left clinging high on the steep north wall of the canyon.

The thick lava flow that underlies Rampart Ridge, just west of Longmire, is a good example of a fairly old intracanyon flow that now stands up as a prominent ridge. This flow originally poured into and clogged the upper canyon of the Nisqually River. Part of the river was displaced to the east side of the intracanyon flow and proceeded to cut the valley of the present-day Nisqually River; the remainder of the river cut down along the west side of the flow and formed the valley of Kautz Creek. The thick intracanyon flow resisted erosion and, therefore, has been left behind as a ridge.

These old intracanyon flows stand in sharp contrast to the relatively young flows lying at the bottom of a few of the present-day canyons. One of the best examples forms the low sharp ridge along the south side of Stevens Creek. Before this flow spilled into the canyon, Maple Creek joined Stevens Creek near the present site of Sylvia Falls. The lava, however, overran and blocked this junction and diverted the waters of Maple Creek eastward along its southern margin. This new segment of Maple Creek now winds around the end of the intracanyon flow and joins Stevens Creek about a mile farther downstream.

The main cone of Mount Rainier rises high above the projecting fingers of intracanyon lava and is built from hundreds of thin lava streams sloping downward from the summit. The flows are thin because the fluid lava drained quickly from the steep upper slopes of the cone, but they thicken toward the lava apron at its base.

Closer inspection shows, however, that many of the thin flows high on the mountain are highly shattered and grade into sheets of fragmental material called breccia. These formed when hot lava erupted upon and burrowed into slushy snow. Melt water mixed with the hot lava and exploded into steam, violently blasting the flows into bits and pieces. Additional melt water was churned into this debris to form soupy mudflows that cascaded downslope. Many of these mudflows came to rest on the slopes of the mountain and solidified as breccias, but some poured into the river valleys at lower altitudes.

Most of the lava that built the main body of Mount Rainier was erupted from a central vent at the former summit of the mountain. Part of the plug of solidified lava that now fills this vent is exposed in the precipitous east wall of Sunset Amphitheater (map symbol: [Qrp](#)), and its inferred underground shape is shown on the geologic section. Two smaller plugs on the northwestern flank of Mount Rainier mark the position of satellitic volcanoes that erupted relatively small amounts of andesite, rich in conspicuous, pale-green crystals of olivine (map symbol: [Qora](#)). Three thick radial dikes ([Qrp](#)) extending outward from the summit area also fed eruptions of lava to the lower slopes of the mountain. The two most prominent of these, at Puyallup Cleaver and St. Elmo Pass, form resistant ribs that jut above the rocks they intrude.

It has long been recognized that Mount Rainier was once considerably higher than it is today. The truncated lava flows in the upper part of the mountain slant upward to a former summit that was at one time about 1000 feet higher than its present altitude of 14,410 feet. Some geologists have proposed that this upper, missing part of Mount Rainier was blasted off by a violent explosive eruption. However, the apparent lack of fragmental debris that surely would have been scattered over the surrounding area by such an eruption is a puzzling contradiction. Perhaps a better explanation is that large-scale sliding and avalanching, as well as glacial erosion, rapidly ate away the upper part of the mountain. Still a third alternative is that part of the former summit may have collapsed into the vent when the column of lava filling it had temporarily subsided.

The most recent eruptions at Mount Rainier were comparatively small, but they produced features that are easily recognized. The present summit of Mount Rainier lies at the top of a low lava cone that grew astride the broken eastern rim of the mountain. The top of this cone is dimpled by two well-preserved craters whose rocky rims protrude above the snow and ice. The smooth, undissected outline of the cone indicates that it grew after the last main period of glaciation in late Pleistocene time. This cone is best seen when viewing Mount Rainier from the east; from Tipsoo Lake its profile is unmistakable.

The recent eruptions also blasted minor amounts of pumice and ash high into the air, and this material then rained down upon much of the park. The visitor to Yakima Park will easily recognize the brown, popcorn like fragments of pumice lying directly on the surface of the ground. These fragments were showered upon the area during the latest eruptions from Mount Rainier, about 600 years ago. The airborne debris from older eruptions lies below this young blanket of pumice. The total thickness of these deposits ranges from less than an inch to only a few feet, and in many places this loose material has been completely eroded away.

Larger-scale erosion is rapidly destroying Mount Rainier. The glaciers have carved deeply into all sides of the mountain and are one of the most effective agents of erosion. The narrow riblike cleavers between the glaciers give some idea of the original girth of the mountain, and they also show how much of it has been eroded away. Part of the material gouged off by the glaciers can be seen in the low ridges of bouldery debris, called moraines that choke the headwaters of the rivers draining the mountain. Most of this debris was bulldozed down by the glaciers and then left in great heaps when the glaciers retreated.

Avalanches and rockfalls are also reducing the size of Mount Rainier. Any climber who has traversed the ledge below Gibraltar Rock on a warm summer's afternoon will vow that the mountain is literally falling apart. Rocks constantly tumble from the jagged cleavers, and huge avalanches of snow, ice, and frost-rifted lava frequently thunder down from high on the mountain and spill onto the glaciers below. Dust clouds given off by large rockfalls and avalanches sometimes billow to great heights, and, on several occasions, have led to erroneous reports that Mount Rainier was erupting.

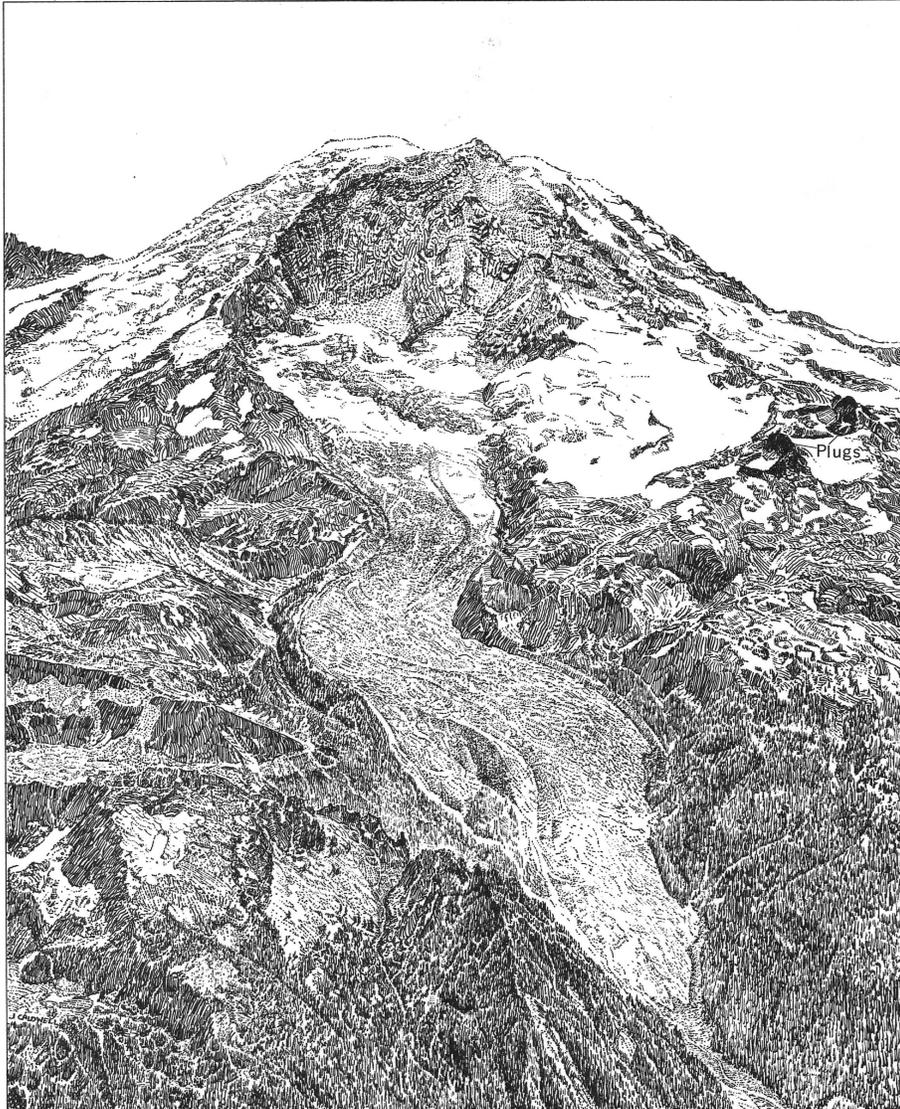
Mudflows originating on the lower slopes of Mount Rainier are especially effective in moving enormous volumes of debris from the mountain. About 5000 years ago a huge volume of water-soaked moraines and other unconsolidated material broke loose and traveled many miles down the valley of the White River. A similar, but much smaller, mudflow carrying 50 million cubic yards of solid material formed when the end of the Kautz Glacier collapsed and surged down the valley of Kautz Creek on October 2, 1947. This mudflow, carrying huge blocks of ice and rock, and a tangle of uprooted trees, spread out over a narrow plain in the lower valley of the Kautz. Here it partly buried and killed the dense forest on the valley floor and temporarily dammed the Nisqually River, 6½ miles from the foot of Mount Rainier.

It is frequently asked whether Mount Rainier may one day again burst forth in eruption. This question cannot be answered with assurance; one can only point to the mountain's ever-declining volcanic activity since its youthful period of rapid growth. The early eruptions produced huge volumes of lava which spread far beyond the base of the cone. Later, as the mountain grew higher, the flows that reached the canyons at the base of the cone grew smaller and less frequent. The volcano achieved its maximum altitude before the last major period of glaciation, and, since that time, its growth has not kept pace with the vigorous erosion that is rapidly destroying the cone. The dwindling post-glacial activity has produced only the new summit cone and the relatively small showers of pumice and ash. Thus the once-mighty fires of Mount Rainier volcano have long since died to coals, but who can say whether the last glowing ember has flickered out?

*Extracted from:* ([Geologic Map and Section of Mount Rainier National Park](#)).

## I-432 Figures

**Figure 1: Mount Rainier from the Northwest**



The Carbon Glacier bites deeply into the mountain; the steep cliffs of Willis Wall rise 3600 feet above the head of the glacier. Satellitic plugs of olivine andesite protrude through the lower slopes of Mount Rainier (right side), and the smooth outline of the youthful summit cone is silhouetted against the skyline at the top of the mountain.

*Extracted from:* ([Geologic Map and Section of Mount Rainier National Park](#)).

**Figure 2: Mount Rainier from the West**



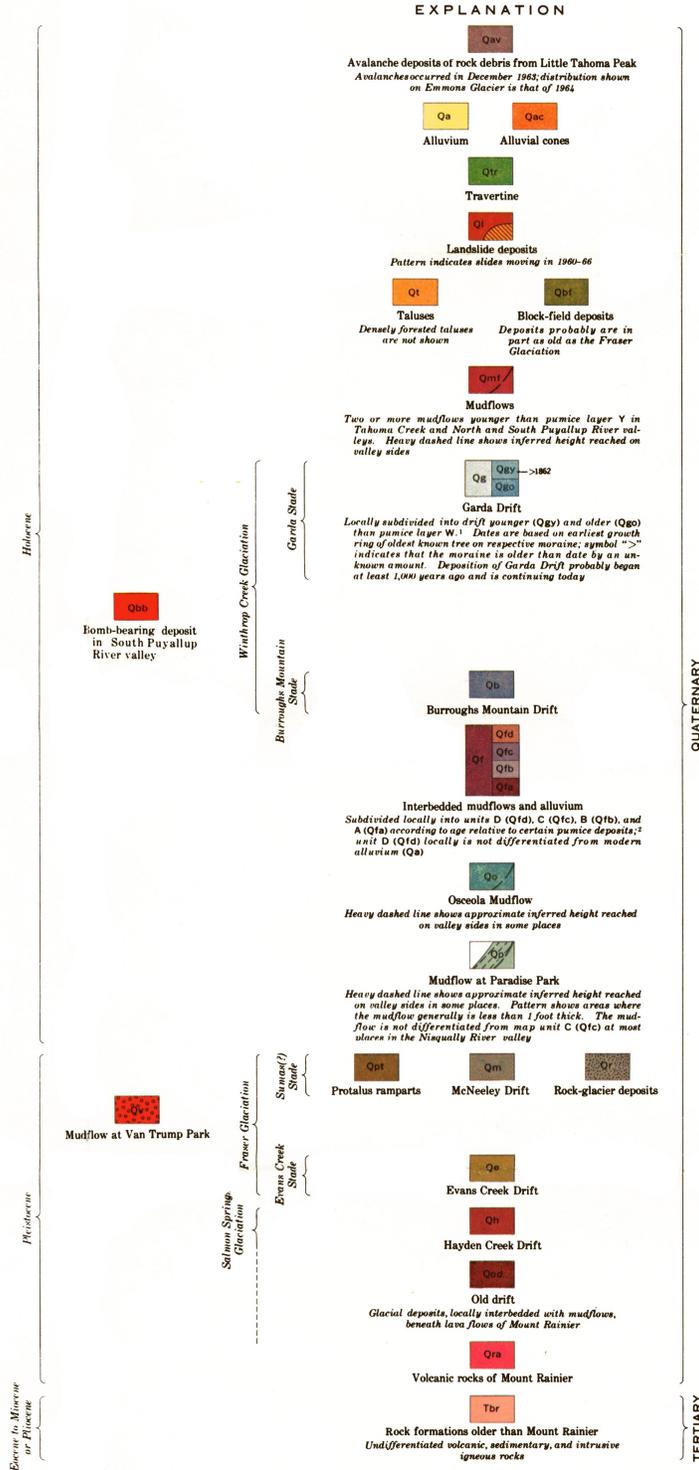
Upper part of mountain is built of thin lava flows and layers of breccia. Massive plug of the volcano is exposed in east wall of Sunset Amphitheater; twin craters at top of small summit cone barely visible.

Extracted from: ([Geologic Map and Section of Mount Rainier National Park](#)).

### **Surficial Geology of Mount Rainier National Park (Bulletin 1288)**

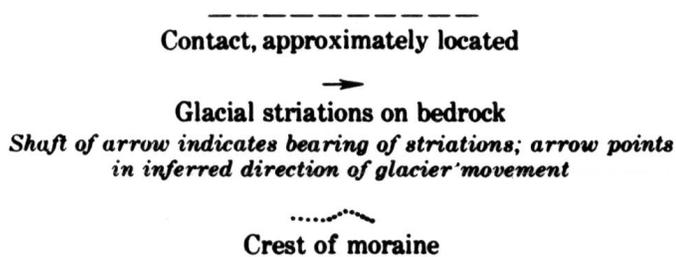
Crandell, D.R., 1969, Surficial Geology of Mount Rainier National Park, Washington: U.S. Geological Survey, Bulletin 1288, scale 1:48,000 (*GRI Source Map ID 2077*).

Bulletin 1288 Correlation



Extracted from: [\(Surficial Geology of Mount Rainier National Park\)](#).

## Bulletin 1288 Map Legend

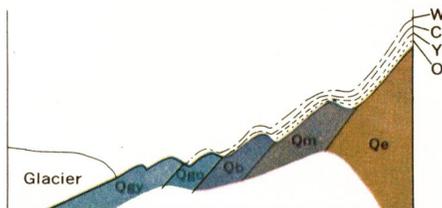


Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

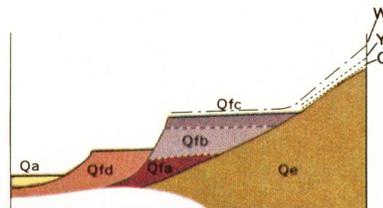
## Bulletin 1288 Pumice Deposits

Pumice deposits of Holocene age that are most useful for determining the age of surficial deposits are as follows:

Pumice layer	Source volcano	Age, in years before present
w	Mount St. Helens	450
c	Mount Rainier	>2,150 <2,500
y	Mount St. Helens	>3,250 <4,000
o	Mount Mazama	About 6,600



<sup>1</sup> Idealized cross section of lateral moraines of different ages on a valley wall, showing their age relation to pumice deposits



<sup>2</sup> Idealized cross section of interbedded mudflows and alluvium, showing their age relation to pumice deposits

Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

## Bulletin 1288 Drift Type Localities

(M)

Type locality of McNeeley Drift between  
Yakima Park and McNeeley Peak

(H)

Type locality of Hayden Creek Drift  
along Mowich Lake Road

Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

## Bulletin 1288 Report

### Surficial Deposits Record Recent Geological Events

Much of the ground surface around Mount Rainier volcano is directly underlain by loose geologic deposits that veneer the hard rock formations. Examples of these deposits are sand and gravel bars along the rivers, ridges of loose rock debris beside the glaciers, and sloping aprons of rock fragments beneath almost every cliff. Even though they are generally thin and inconspicuous when compared with the rock formations, these surficial deposits are clues to geologic events that have profoundly influenced the shape of the park's landscape. Thus, from the character and extent of glacial deposits one can judge the age and size of former glaciers that carved the cirques and deep canyons of the park; from the mudflows which streamed down nearly every valley one can infer the age and size of huge landslides of the past that helped determine Mount Rainier's present shape; and from the pumice deposits some of the volcano's recent eruptive activity can be reconstructed.

The map (plate 1, in pocket) that accompanies this description of the surficial deposits of Mount Rainier National Park shows the location of the various geologic formations, and the explanation shows the formations arranged in order of their relative age, with the oldest at the bottom. The text describes the surficial deposits in sequence from older to younger. A discussion of the pumice deposits of the park, which were not mapped, is followed by a description of the formations shown on the geologic map.

Inspection of the geologic map may lead the viewer to question why the surficial deposits are shown in more detail in a zone several miles wide around the base of the volcano than elsewhere. This is partly because the zone is largely near or above timberline, relatively accessible, and the surficial deposits there can be readily recognized, differentiated, and mapped. In contrast, access is more difficult in the heavily timbered parts of the park, and surficial deposits there are generally blanketed by a dense virgin forest and are rarely exposed. Geologic investigations in such areas of the park were of a reconnaissance nature.

### How Surficial Deposits Are Formed

Most of the surficial deposits were formed by geologic processes that occurred over and over again, and some of these processes are still going on today. One kind of geologic process is the erosion of rock by glaciers, the transportation of the resulting debris downvalley by the ice, and the eventual deposition of the debris at and beyond the glacier margins. The resulting surficial deposits are referred to collectively as glacial drift. They include rock debris deposited by glacier ice as well as sand and gravel formed by melt water from glaciers. The term till refers to an unsorted mixture of rock debris formed directly by a glacier. Moraines are ridges of till that have been deposited along the sides of a glacier (lateral moraines) or at its front (end moraines).

A second geologic process responsible for many surficial deposits in the park is landsliding. Some large slides of the past became mixed with water as they moved downslope into valleys and formed mudflows. Mudflows are mixtures of water and rock debris of many sizes and during movement resemble wet concrete. Falls of masses of rock from cliffs are also a type of landslide; they range in size from small pieces that accumulate at the base of the cliff and form a sloping talus of angular rock fragments to falls of whole sections of a cliff. Rockfalls that become broken into material of many sizes sometimes move rapidly far downvalley as avalanches of rock debris.

A geologic process that is going on today just as it did in the past is the erosion, transportation, and deposition of rock debris by streams and rivers. The sand and gravel deposits in river bars and terraces that result from this process are called alluvium.

Still another geologic process that has resulted in some widespread but thin surficial deposits is volcanism. Within the last 10,000 years or so, Mount Rainier has repeatedly erupted clouds of pumice that have settled to the ground over much of the eastern part of the park. Pumice is a type of lava that is so full of gas bubbles that it is light enough to float on water. Because of its light weight, pumice can be transported great distances by wind.

Some geologic processes other than those mentioned are responsible for a few of the surficial deposits in the park; these will be discussed as the specific deposits are described.

### **Landslides, Mudflows, and Mount Rainier's Shape**

Landslides have played an unusually important role at Mount Rainier, both in determining the volcano's shape and in forming some of the park's surficial deposits. Although landslides are common features elsewhere, those at Mount Rainier are exceptionally large. The largest one destroyed much of the volcano's former summit about 5,700 years ago. The top of Mount Rainier today is the crest of a small lava cone that perhaps is only about 2,000 years old. The cone occupies a broad depression whose broken rim is represented by Gibraltar Rock, Point Success, and the ridge between Liberty Cap and Russell Cliff ([fig. 1](#)). The broad depression resulted from great landslides of rock from the former summit of the volcano, which had become decomposed to clay and weakened by hot volcanic gases and solutions over many centuries. These slides of wet clayey rock formed a truly spectacular mudflow that streamed downvalley from the volcano at least 70 miles.

Similar but smaller slides of clayey rock have occurred repeatedly on other parts of the volcano during the last 10,000 years and have also resulted in clayey mudflows. These mudflows contain clays that originated from long-continued steaming and chemical breakdown of volcanic rocks. Decomposed and altered rocks of this kind at Sunset Amphitheater on the west side of Mount Rainier are part of a central plug of lava that cooled and solidified in a former throat of the volcano. Although its shape is similar to that of depressions carved wholly by glacial erosion, Sunset Amphitheater was probably formed in large part by repeated landslides and is analogous in origin to the former broad depression at the summit of the volcano. Several clayey mudflows in the valleys on the west side of the volcano originated in these slides at Sunset Amphitheater, and the landslide of yellowish-orange clay and altered rock from the same source that lies at the end of Tahoma Glacier ([frontispiece](#)) is no more than a few decades old.

### **Recent Pumice Deposits**

Thin layers of pumice erupted by Mount Rainier and by other volcanoes in the Cascade Range are the most wide spread surficial deposits in the park. Although these deposits are not represented on the geologic map because of their thinness, the distribution of five layers erupted by Mount Rainier is shown in [figure 2](#).

The ages of most of the pumice deposits are known within a few hundred years because wood buried with them can be dated by determining the proportion of radioactive carbon the wood contains. Other surficial deposits that are interbedded with pumice layers of known age can be dated approximately. Elsewhere, the age of a surficial deposit, such as a moraine, can be limited by the presence or absence of a certain pumice layer on top of it (see sketches at the bottom of the map explanation [plate 1]) — if the pumice is present, the deposit must be older; if the pumice layer is not on top, the deposit is younger than the pumice. This method of dating surficial deposits, of course, can be used only in areas covered by the pumice layer in question.

The most distinctive and widespread pumice deposits at Mount Rainier—and those most useful for purposes of dating other surficial deposits—were erupted by two other volcanoes and brought to the park by southwesterly winds. Layer O ([table 1](#)) is about 2 inches thick and blankets the entire park and adjoining region. It can be readily recognized by a distinctive yellowish-orange color ([fig. 3](#)) and a flourlike

texture. When it is studied under the microscope, its characteristics are found to correspond precisely to those of the pumice that was erupted by Mount Mazama volcano at the site of Crater Lake, Oreg., about 6,600 years ago. The extreme fineness of layer O can be attributed to the distance of 250 miles that separates Mount Rainier from Crater Lake.

Pumice layers Y and W originated at Mount St. Helens volcano, which is about 50 miles southwest of Mount Rainier. Both layers cover lobate areas that extend far northeastward from their source. The centerline of the lobe of layer Y lies near the west edge of the park, where the pumice is commonly as much as 18 inches thick. The thickness of layer Y decreases to the east, and the layer is thin or absent in the southeast corner of the park. Layer Y is light yellowish brown ([fig. 3](#)), which helps to distinguish it from layer W, which is white. The center of the lobe of layer W lies near the east boundary of the park, where the pumice is about 2 inches thick.

The thickest and most widespread pumice from Mount Rainier is layer C, which is found throughout the eastern and northeastern parts of the park. Layer X, which represents Mount Rainier's most recent known eruption, was formed about the middle of the last century. It is found only in a small area close to the volcano.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

### Bulletin 1288 Table 1

Table 1. — Characteristics, sources, and ages of pumice layers, Mount Rainier National Park.  
[Based on studies by D. R. Mullineaux]

Pumice layer	Common range of thickness in park		Common range in diameter of pumice fragments (inches)	Color	Source	Approximate age in 1968, or limiting dates (years ago)
	West side (inches)	East side (inches)				
X	Absent	1	1/4—2	Light olive gray	Mount Rainier	100—150
W	0—1	1—3	Medium sand	White	Mount St. Helens	<sup>2</sup> 450
C	Absent	1—8	1/4—8	Brown	Mount Rainier	2,150—2,500
Y	5—20	1—5	Coarse sand	Yellow	Mount St. Helens	3,250—4,000
D	Absent	0—6	1/4—6	Brown	Mount Rainier	5,800—6,600
L	Absent	0—8	1/4—2	Brown	Mount Rainier	5,800—6,600
O	1—3	1—3	Flourlike to fine sand	Yellowish orange	Mount Mazama	About 6,600
R	Absent	0—5	1/8—1	Reddish brown	Mount Rainier	8,750—11,000?

<sup>1</sup>The X pumice occurs as scattered fragments and does not form a continuous layer.

<sup>2</sup>Ages of more than 159 and less than 6,000 years cited in this report are based on radiocarbon determinations which have been corrected by the use of a C<sub>14</sub> half life of 5,730 years and for variations in atmospheric C<sub>14</sub> (H. E. Suess, written communication to Meyer Ruhin, 1968).

Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

## Bulletin 1288 Figures

### Frontispiece



**AVALANCHE DEPOSIT** of yellow-orange clay and rock debris lies on top of Tahoma Glacier on the west side of Mount Rainier. The avalanche originated in rockfalls at the cliffs at the upper left and slid down to the end of the glacier. The cliffs from the headwall of Sunset Amphitheater; Point Success is the peak at the right. The front of the glacier, in the foreground, is about 200 feet high.

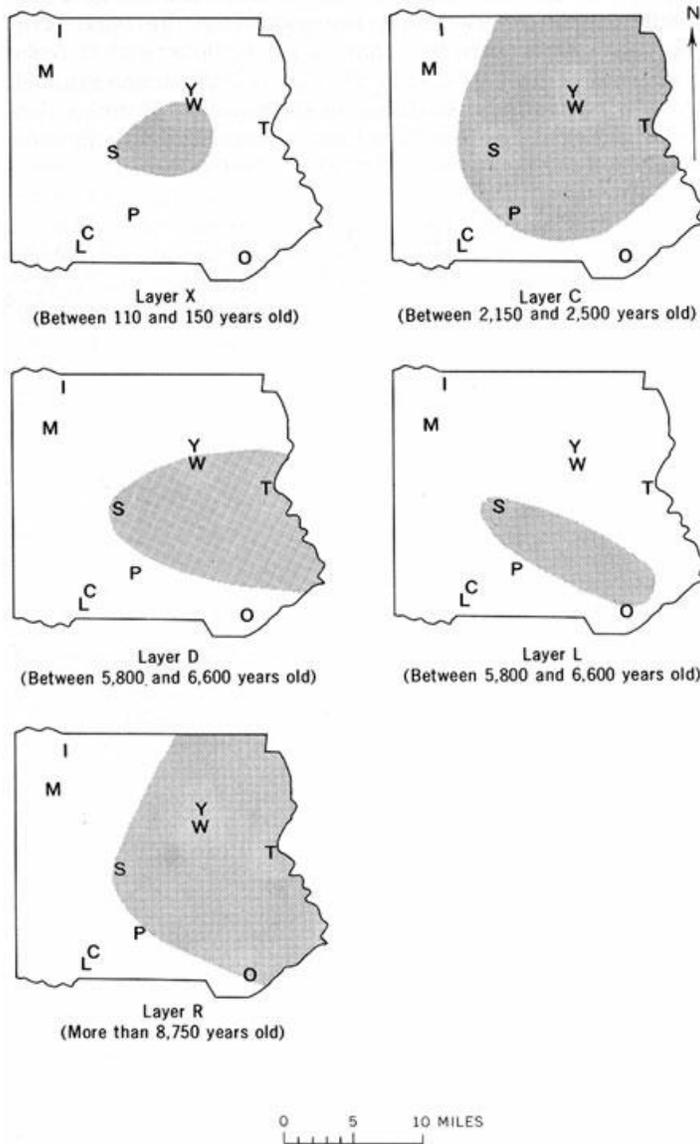
*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 1: East Side of Mount Rainier**

The summit cone lies within a broad depression whose rim is represented by Point Success, Gibraltar Rock, and the ridge between Liberty Cap and Russell Cliff. The depression was formed when the former top of the volcano, which consisted of rock that had been partly altered to clay, slid off to the east and descended Emmons Glacier in a tremendous avalanche that produced the Osceola Mudflow 5,700 years ago. The distance from Point Success to Liberty Cap is 1/4 miles, and the summit crater is about 1,300 feet across.

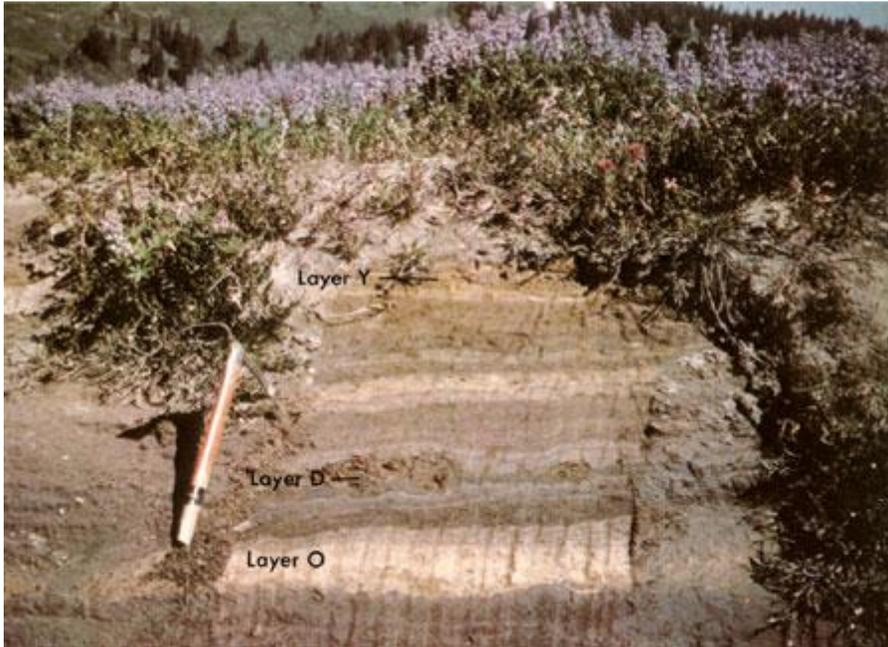
Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 2: Distribution of Pumice Deposits**



In Mount Rainier National Park. Only the pumice layers erupted by Mount Rainier within the last 10,000 years are shown. The extent of layer X is based on the recognition of the pumice at certain localities, regardless of its thickness; other layers are shown wherever they are at least 1 inch thick. Letters represent the following localities: C, Cougar Rock camp ground; I, Ipsut Creek camp ground; L, Longmire; M, Mowich Lake; O, Ohanapecosh camp ground; P, Paradise Park; S, summit crater; T, Tipsoo Lake; W, White River camp ground; and Y, Yakima Park. Based on studies by D. R. Mullineaux.

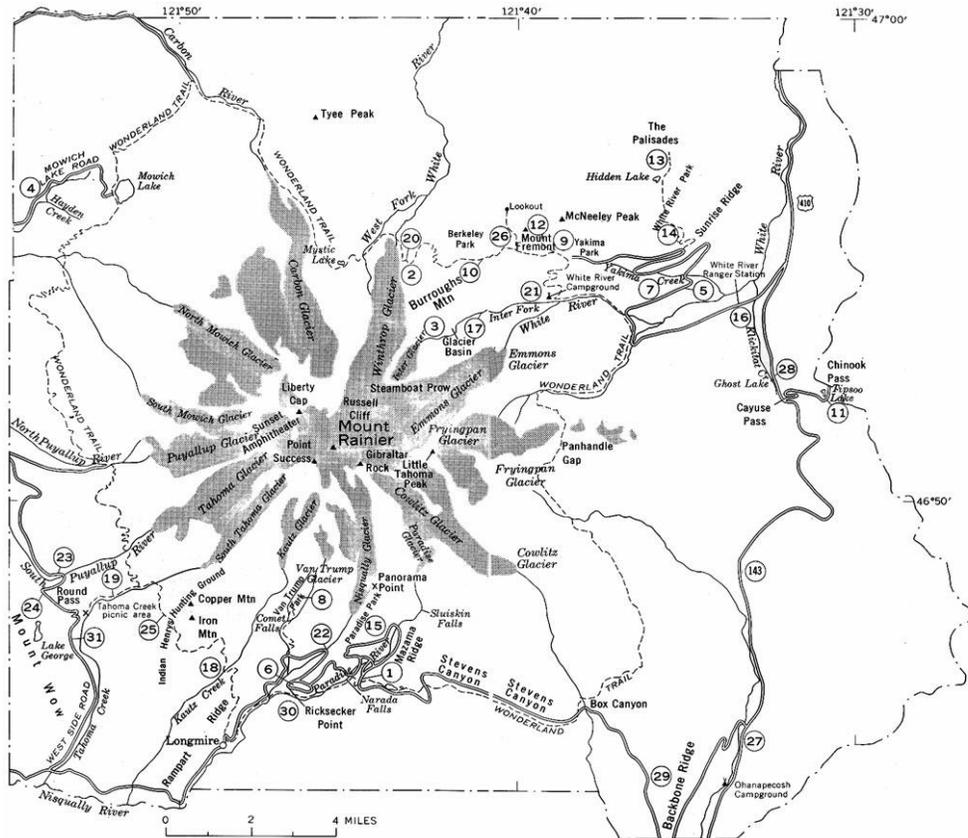
Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 3: Recent Pumice Deposits**

On the floor of a cirque a quarter of a mile southeast of Sluiskin Falls. The yellow bed at the bottom is layer O, which was erupted at the site of Crater Lake, Ore., about 6,600 years ago. The yellowish-brown pumice a few inches above layer O is layer D, which was erupted by Mount Rainier more than 5,800 years ago, and the light-yellowish-brown pumice bed at the top of the outcrop is layer Y, which originated at Mount St. Helens volcano between 3,300 and 4,000 years ago.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

Figure 4: Map of Mount Rainier National Park



Showing localities mentioned in text (numbered).

Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 5: Old Drift**

On the north side of Glacier Basin. The geologic formations, in order of decreasing geologic age, are: 1, Bedrock much older than Mount Rainier; 2, mudflows which came from an old Mount Rainier volcano; 3, old drift, which consists mostly of very bouldery till; 4, an old andesite lava flow from Mount Rainier; 5, a red volcanic rubble from Mount Rainier; 6, a younger andesite lava flow from Mount Rainier; and 7, an andesite dike. The age relation of the dike to the younger lava flow is not known. The yellow deposit in the right foreground is a Garda moraine of Inter Glacier; it is about 200 feet high and consists almost wholly of Osceola Mudflow, which was eroded from the floor of the basin and redeposited by the glacier. The deposits in the left foreground and middle distance are alluvium younger than the moraine.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

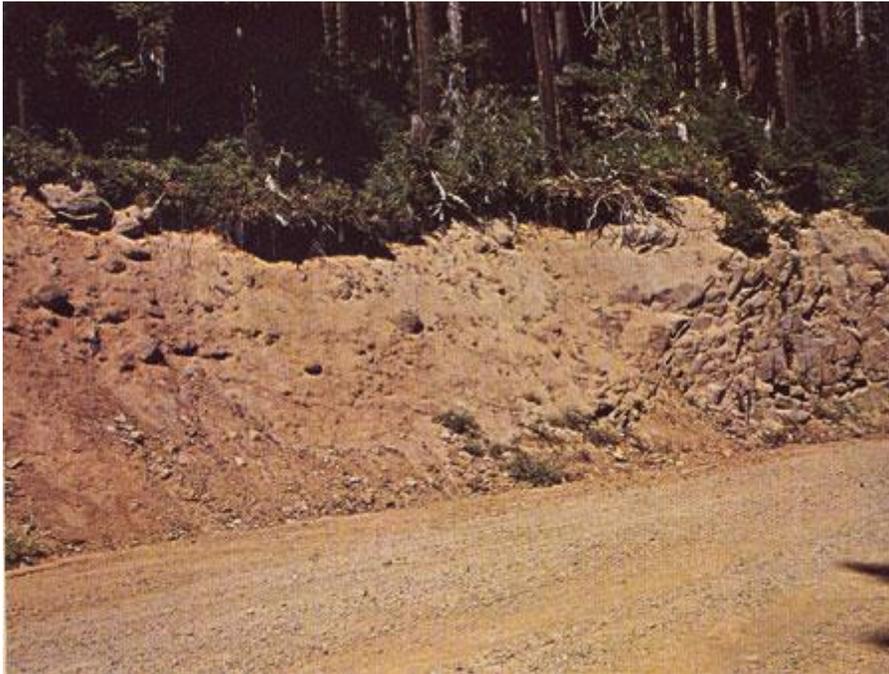
**Figure 6: Bouldery Till**



Exposed in a gully on the north side of Glacier Basin is part of the old drift. The boulders and smaller stones of various colors in the till are derived from the bedrock that underlies the volcano. The stones are contained in a very hard and compact matrix of brownish-gray silt and sand.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 7: Hayden Creek Till**



Along the Mowich Lake Road. The thick brown oxidized zone at the top of the till is typical of the Hayden Creek Drift. Bedrock at the right is much older than Mount Rainier volcano.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

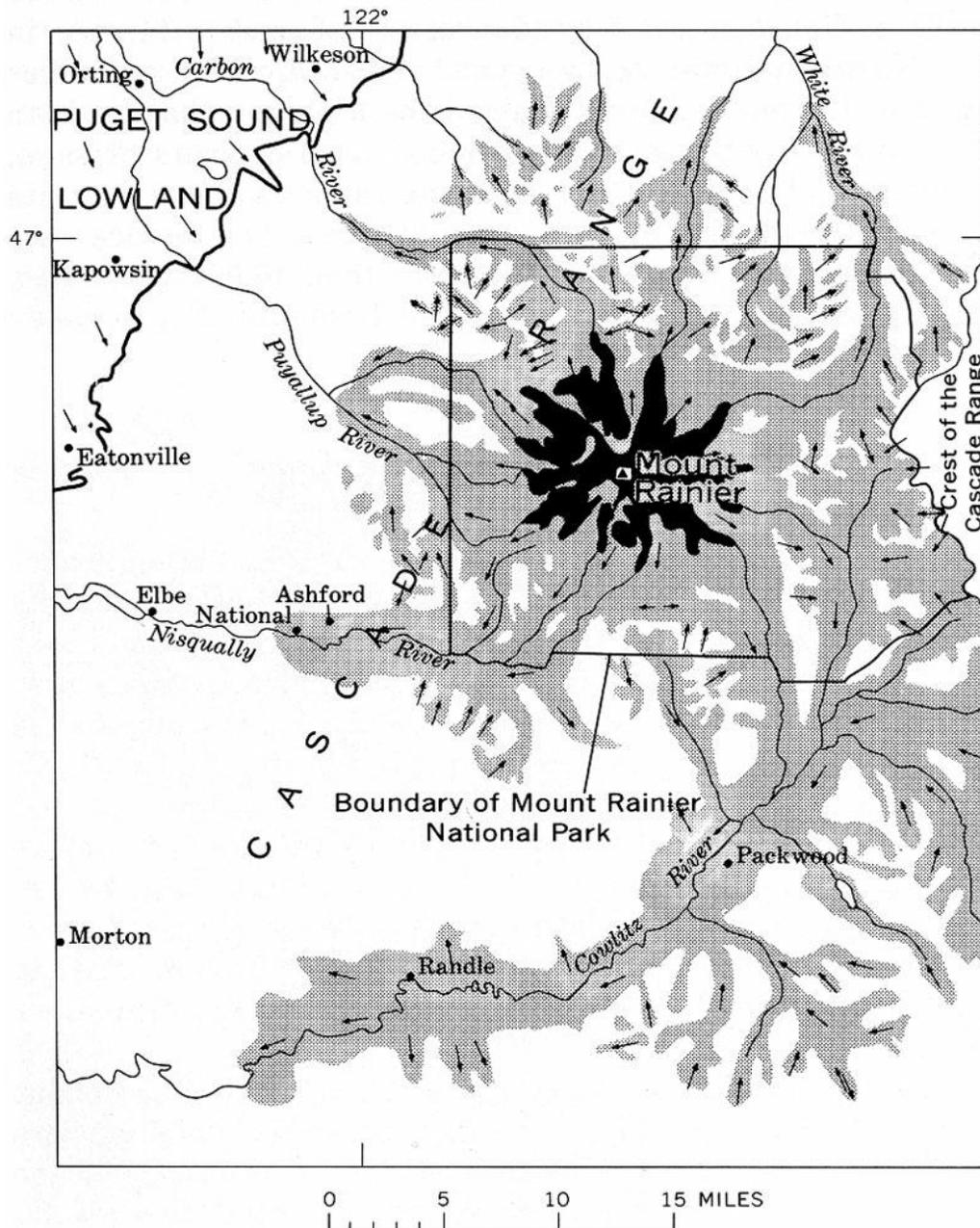
**Figure 8: Yellowish-Orange Rinds**



On these stones of dark-gray volcanic rocks are the result of weathering over a long period of time. Weathered rinds like these, but about half as thick, are present on stones near the surface of the Hayden Creek Drift.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

Figure 9: Extent of Glaciers



At Mount Rainier and in the adjacent mountains during the most recent major glaciation is shown by stipple pattern. The heavy black line at the upper left marks the boundary between the Puget Sound lowland and the Cascade Range. This line also represents the southeast edge of a massive glacier in the lowland which originated in southwestern Canada and reached this part of the lowland about 14,000 years ago. The arrows show the direction of glacier movement. Black areas are covered by glaciers today.

Extracted from: ([Surficial Geology of Mount Rainier National Park](#)).

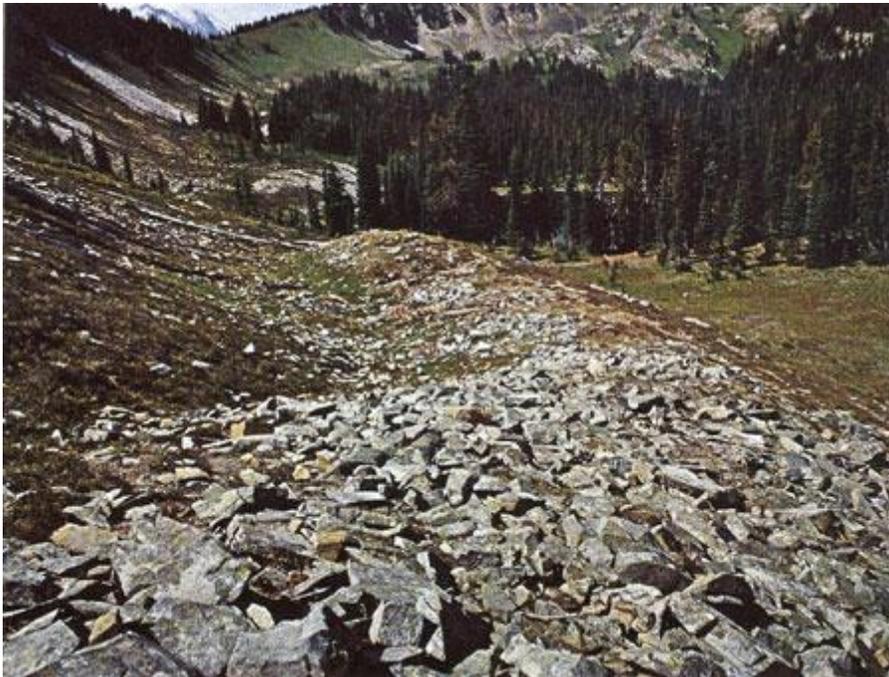
**Figure 10: Rock-Glacier Deposit**



In the foreground is an accumulation of light-colored rock debris derived from the cliffs of The Palisades in the northeastern section of the park. The deposit covers an area of about 100 acres and is 100—300 feet thick. The steeply sloping deposit of rock debris just below the cliffs is a talus.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

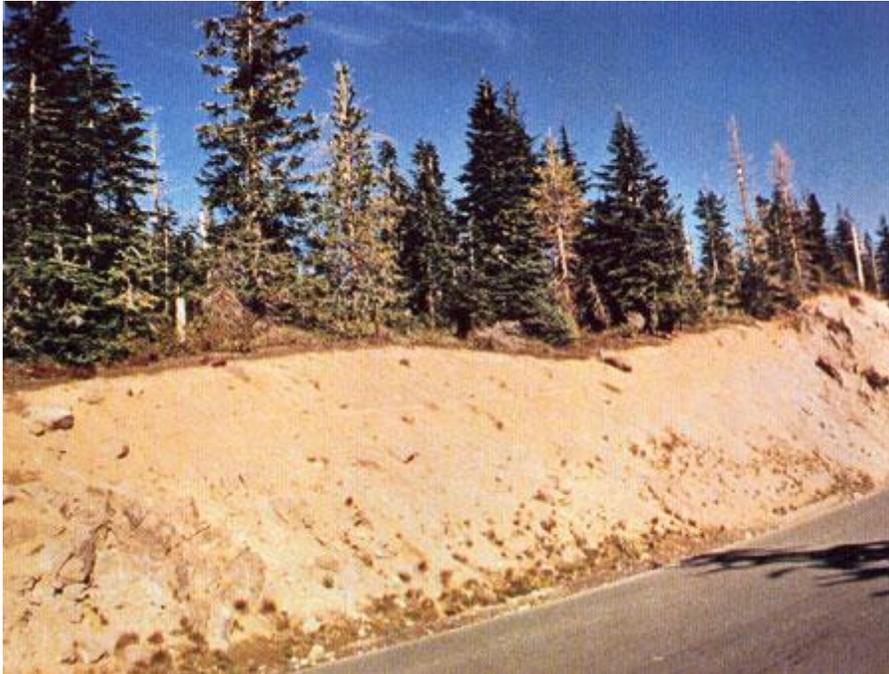
**Figure 11: Protalus Rampart**



On the north side of Sunrise Ridge is separated from the partly vegetated talus on the left by a depression 5—6 feet deep and 20—30 feet wide. A thick wedge-shaped snowbank blanketed the talus and the depression when the arcuate rampart was formed.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

### Figure 12: Pumice Layer O



From Mount Mazama (Crater Lake) forms a thin yellow band at the base of the yellowish-orange mudflow that blankets Paradise Park. This outcrop is at Ricksecker Point, and its height above the floor of the adjacent Paradise River valley indicates that the mudflow was temporarily at least 800 feet deep here.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 13: Osceola Mudflow**



Is exposed on the south bank of Inter Fork. Slope wash from the bouldery yellow mudflow has nearly hidden the underlying gray Evans Creek till, which can be seen at the lower left.

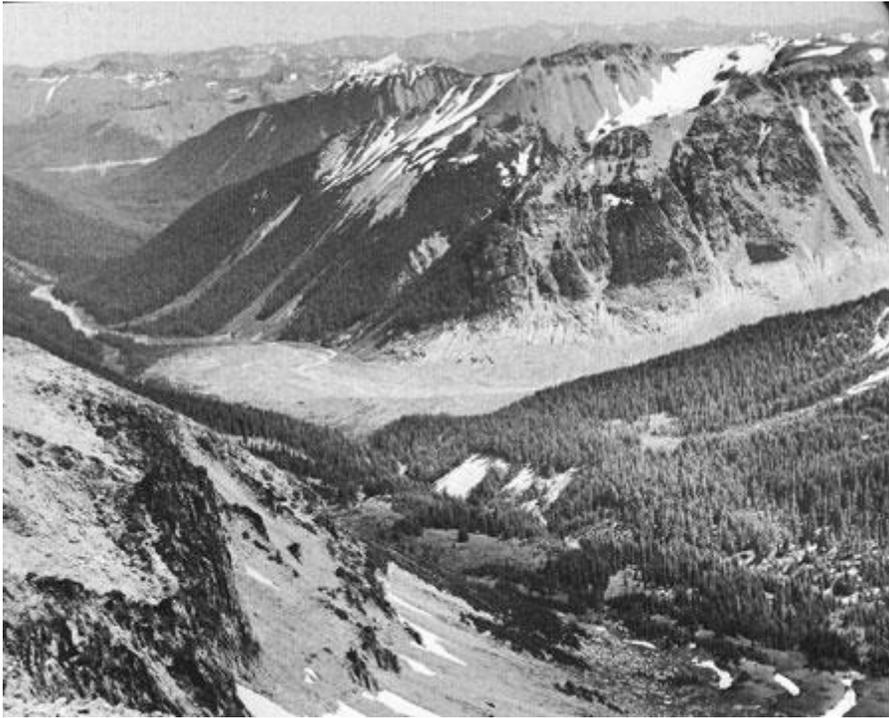
*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 14: Pumice Layer C**

Forms a thin brown veneer on the drift in the foreground and on the Burroughs Mountain moraine in the center of the photograph. This pumice was erupted by Mount Rainier between 2,150 and 2,500 years ago. The Garda moraine of Fryingpan Glacier at the left has no pumice on it, and thus is younger. The large boulder in the middle foreground is about 6 feet long. This locality is at an altitude of 7,500 feet about a mile southwest of Panhandle Gap.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 15: End Moraine**



Of Garda Drift formed by Emmons Glacier is a hummocky accumulation of bare rock debris in the center of the White River valley. When the ice front stood at the moraine, the upper surface of the glacier coincided with the conspicuous sloping trimline in the trees on the opposite valley wall. The exposure in the center fore ground is that shown in figure 13.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 16: Breadcrust Bomb**



On the left shows a typical cracked and segmented surface formed during cooling; the other bomb is broken open to show the black bubbly interior. The bombs are about 10 inches in diameter.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 17: Mudflow**



From Mount Rainier is the dark-brown deposit above the head of the pick; it lies on top of yellow pumice (layer Y) from Mount St. Helens which is between 3,250 and 4,000 years old. This locality is on the north side of the North Puyallup River valley a mile west of the park boundary. Its height of about 240 feet above the valley floor indicates that the mudflow was temporarily at least 240 feet deep here. The pumice is unusually thick.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 18: Alluvial Cone**



At the east base of Mount Wow. The largest blocks in the deposit are about 20 feet in diameter.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

**Figure 19: Avalanche Deposit**



Of rock debris in the foreground originated in rockfalls from Little Tahoma Peak. The deposit buried the former floor of the White River valley to depths as great as 100 feet. The boulder on the ridge at the left has dimensions of about 24 by 30 by 46 feet.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

### **Bulletin 1288 Further Reading**

- Crandell, D. R., and Fahnestock, R. K., 1965, Rockfalls and avalanches from Little Tahoma Peak on Mount Rainier, Washington: U. S. Geological Survey Bulletin 1221—A, 30 pages. A description of the seven successive landslides of December 1963 that buried the upper White River valley under thick deposits of rock debris.
- Crandell, D. R., and Mullineaux, D. R., 1967, Volcanic hazards at Mount Rainier, Washington: U.S. Geological Survey Bulletin 1238, 26 pages. A discussion of the eruptive history of the volcano during the last 10,000 years and the anticipated effects of similar future eruptions.
- Fiske, R. S., Hopson, C. A., and Waters, A. C., 1963, Geology of Mount Rainier National Park, Washington: U. S. Geological Survey Professional Paper 444, 93 pages. A technical description of the rock formations of the park.
- Fiske, R. S., Hopson, C. A., and Waters, A. C., 1964, Geologic map and section of Mount Rainier National Park, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I—432. A relatively nontechnical discussion of the geological evolution of the park as recorded by the rock formations.
- Sigafoos, R.S., and Hendricks, E. L., 1961, Botanical evidence of the modern history of Nisqually Glacier, Washington: U. S. Geological Survey Professional Paper 387—A, 20 pages. A description of the recent moraines of several glaciers and an explanation of how they are dated by counting the growth rings of trees growing on them.

*Extracted from:* ([Surficial Geology of Mount Rainier National Park](#)).

## GRI Digital Data Credits

This document was developed and completed by Derek Witt and Stephanie O'Meara (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory(GRI) Program. Quality control and some format edits of this document by Stephanie O'Meara. This document was produced from an earlier GRI version of the document produced by Victor deWolfe (Colorado State University) and Stephanie O'Meara.

The information in this document is intended to accompany the digital geologic-GIS map(s) and other digital data for Mount Rainier National Park, Washington (MORA) developed by Derek Witt and Stephanie O'Meara (Colorado State University) (see the [GRI Digital Maps and Source Map Citations](#) section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps). The earlier GRI GIS version of this dataset including digitization by Victor deWolfe and Stephanie O'Meara.

GRI finalization by Stephanie O'Meara (Colorado State University).

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