Geologic Features and Processes

This section provides descriptions of the most prominent and distinctive geologic features and processes in Mount Rainier National Park.

At present, the Cascade Province contains four national parks and one volcanic monument: Mount Rainier National Park (WA), North Cascades National Park (WA), Crater Lake National Park (OR), Lassen Volcanic National Park (CA) and Mount St. Helens Volcanic Monument (WA), managed by the U.S. Forest Service. These parks, as well as other Cascade Mountain areas, contain world- class examples of volcanic and glacial features. The geologic features and processes in MORA are divided into the following sections:

- Glacial Features and Glacier Processes
- Volcanic Features
- Thermal Features and Ice Caves

Glacial Features and Glacier Processes

Glaciers are highly effective erosional agents, shaping mountains into picturesque landforms with such distinctive erosional features as *horns* (peaks), *cirques* (deep, bowl- shaped, steep- walled recesses in a mountain), *glacial valleys* (U- shaped valleys), and *arêtes* (rugged crests or ridges between two mountains). Tipsoo Lake, Crescent Lake, and Mowich Lake are examples of cirque lakes at MORA. Some tributary streams end as waterfalls at the mouth of *hanging valleys* like Christine Falls and Comet Falls. Carved by glaciers, hanging valleys are erosional features in which the floor of the valley is notably higher than the level of the valley to which it leads. Most of the glacial landforms on Mount Rainier are the result of Pleistocene glaciers that formed 25,000 to 10,000 years ago and continue to erode the mountain today.

Depositional features are formed from material eroded from the mountain that is transported down valley and deposited as rock debris termed *drift*. Glacial *till* is unconsolidated, poorly sorted drift that forms end and lateral *moraines,* undulating mounds composed of boulders, cobbles, pebbles, sand, silt, and clay clasts. Many of the deposits left by mudflows, debris flows, and avalanches also are associated with the glaciers on Mount Rainier.

The valley glaciers that create the backcountry of Mount Rainier radiate like spokes on a wheel from the summit of the volcano (Figure 1). About 35,000 years ago, the Cowlitz Glacier on the southeast side of the mountain extended 65 miles (105 km) from the mountain and about 8 miles (13 km) west of the present town of Randle (Kiver and Harris, 1999). The end of the Pleistocene Ice Age came about 10,000 years ago, about the same time as the eruptive event that formed the main cone of Mount Rainier.

The extreme height and massive character of the volcano allows it to intercept moisture- laden westerly winds from the Pacific and to receive abundant snowfall that helps maintain glacial cover. For example, during the winter of 1971- 1972, slightly more than 102 feet (31 m) of snow fell on the mountain, setting a world's record at an official weather station (Kiver and Harris, 1999). Since the mid- 1800s, however, the glaciers have lost as much as 35 percent of their surface area. This trend is synchronous with glacier retreat recorded elsewhere around the world and reflects global warming trends from natural perturbations and human influences. From 1900 to 1960, the Nisqually Glacier retreated about 1 mile (1.6 km) upstream from the old highway bridge (Kiver and Harris, 1999). Paradise Ice Caves, once a major attraction for visitors, collapsed in the fall of 1991 due to the effects of global warming.

The glaciers of Mount Rainier form the largest glacier system in the conterminous United States. Some of the glaciers originate from the summit of the volcano while others extend down the mountain flanks from cirques located in the high- precipitation zone at middle elevations. Linear rock ridges or arêtes, locally known as *cleavers*, separate the glaciers. The Willis Wall is the 3,600- foot- high (1,100 m) vertical headwall that marks the Carbon Glacier cirque. Over a mile wide, the Carbon Glacier cirque is the largest in the Cascade Mountains (Kiver and Harris, 1999).

Over one cubic mile of snow and ice is estimated to perpetually cover Mount Rainier. Only a relatively thin veil separates this ice from the "Mountain of Fire". If this ice were to melt during an eruption, huge floods and mudflows would easily reach the densely populated areas in the Puget Lowland.

The following points of interest are associated with Mount Rainier glaciers or glacial processes. Emmons, Ingraham (Cowlitz- Ingraham), Nisqually, Tahoma, and Winthrop glaciers are the predominant glaciers originating on the summit of Mount Rainier.

Emmons Glacier: Named for geologist, Samuel F. Emmons, the Emmons Glacier is the largest glacier in the contiguous United States. Located on the east slope of Mount Rainier, the Emmons Glacier covers 4.3 square miles (11.1 sq km). A landslide in 1963 covered the lower glacier with rock debris, which insulates the ice from melting. As a result if irregular melting, a vast hummocky topography has formed over the area.

Cowlitz- Ingraham Glacier: The Cowlitz- Ingraham Glacier is currently thinning and retreating although it made a notable advance in the mid- 1970s and continued to slowly advance until the mid- 1980s.

Nisqually Glacier: One of the most accessible glaciers on Mount Rainier, Nisqually glacier can be viewed from Nisqually and Glacier Vistas. Nisqually Glacier holds the record for the fastest measured downhill movement for a Mount Rainier glacier: 29 inches per day (74 cm/d). The glacier thinned by 53 feet (16 m) in the region immediately west of Glacier Vista between 1985 and 1991, but the retreat may be slowing.

Winthrop Glacier: With an area of 3.5 square miles (9.1 sq km), the Winthrop Glacier is the second largest glacier on Mount Rainier. The glacier extends from the summit to the 4,700- feet level (1,433 m) of the West Fork White River Valley. Winthrop Glacier was named for Theodore Winthrop who visited the mountain in 1853, described his experiences in his book *Canoe and Saddle*, and died on the field of battle during the Civil War.

Carbon Glacier: Measurements of the Carbon Glacier, the largest in the park, recorded a thickness of over 700 feet (215 m). Although the third largest glacier by area on Mount Rainier, Carbon Glacier has the greatest thickness and volume (0.2 cubic miles) of any glacier in the contiguous United States. It is 5.7 miles long (9.2 km), which makes it also the longest glacier on Mount Rainier. Beginning just below the imposing 4,000- foot- high (1,219 m) Willis Wall, the glacier's terminus is surrounded by mature forest and shrubbery at an altitude of 3,500 feet (1,067 m).

Kautz Glacier: Kautz Glacier, named in honor of Lieutenant (later General) A.V. Kautz, is one of the primary glaciers on the mountain. In 1857, Kautz made the first attempt to scale the peak by climbing along the edge of the glacier that bears his name. He failed to reach the summit by only a few feet. Kautz Creek originates in the Kautz Glacier and flows into the Nisqually River.

Paradise Glacier: The Paradise Glacier area was one of the main attractions for visitors in the early part of the twentieth century. Because of this attraction, the Paradise Inn was built and opened for business in 1917.

Russell Glacier and Wilson Glacier: These two glaciers are tributary glaciers of major glaciers in the park. Russell Glacier is named after Professor Israel C. Russell, the first scientist to describe the glaciers of the park, and is one of the largest inter- glaciers of the park. It is a tributary to the Carbon Glacier on the north side of Mount Rainier.

Wilson Glacier is a tributary to the Nisqually Glacier on the mountain's south side. It was named for A.D. Wilson. In 1870, Wilson and Professor S.F. Emmons made the second successful ascent of Mount Rainier.

Stevens Glacier, Van Trump Glacier, and Sluiskin Falls: The Stevens Glacier and the Van Trump Glacier are on the southern slope of the mountain. In 1870, Philemon Beecher Van Trump and General Hazard Stevens made the first successful ascent to the summit of Mount Rainier. The Yakima Indian brave, Sluiskin, guided the two men. They named the falls at the head of the Paradise River after their guide.

Sunset Amphitheatre: Chiseled and dredged by rockslides, glacial erosion, and frost action, Sunset Amphitheatre is a cirque- like gouge near the summit of the mountain. Puyallup Glacier originates in Sunset Amphitheatre. A cliff collapse that formed this cirque may have triggered the Electron Mudflow about 500 years ago. This mudflow inundated at least 14 square miles (36 sq km) of Puget Sound Lowland and formed the valley surface around Orting, Washington.

Volcanic Features

The eruption of Mount Rainier also left some distinctive volcanic features. Summit features, rock walls, and satellite volcanoes rim the mountain.

Columbia Crest, Liberty Cap, Point Success: These three distinct summits are high points at the top of Mount Rainier. At 14,410 feet (4,392 m), Columbia Crest is the highest and lies in the rim of a small recent lava cone. The cone is indented by two craters. The larger of the two is about one- quarter mile (0.4 km) in diameter, and both craters are nearly filled with snow and ice. Volcanic heat and steam have melted a system of tunnels and caves in the ice. Liberty Cap and Point Success are remnants of the sides of an old, high cone.

Echo Rock and Observation Rock: Echo Rock and Observation Rock are dissected satellite volcanoes. Olivine andesite erupted from these satellite volcanoes on the northwestern flank of Mount Rainier.

Little Tahoma and McClure Rock: Northwest American Indians named the mountain Takhoma, Tahoma, Taco- bet and other names that mean "big mountain", or "snowy peak", or "place where the waters begin". Little Tahoma is a prominent rock outcrop on the east side of Mount Rainier.

McClure Rock is a prominent point on the southern shoulder of the mountain. The point was named for Professor McClure, University of Oregon, who fell and died while doing scientific research on the mountain.

Ptarmigan Ridge and Wapowety Cleaver: The rugged surface surrounding Mount Rainier is evidence of thick intra- canyon flows. At least 1,200 feet (366 m) thick, Ptarmigan Ridge is an example of a thick flow that was once confined in a canyon. Since deposition, the canyon walls have eroded away, leaving the flow as a resistant ridge in the surrounding landscape.

Wapowety Cleaver is another ridge of rock located between the Kautz and the Wilson Glaciers. Kautz climbed the ridge in 1857 and the ridge was named after Kautz's Indian guide.

The Palisades: Located at the northwestern corner of White River Park, The Palisades form a great cliff of columnar- jointed black rock that rises abruptly from the headwaters of Lost Creek. The cliff is composed of a rhyodacite welded tuff that is as much as 800 feet (244 m) thick.

Willis Wall: Willis Wall forms the rear wall of the cirque of the Carbon Glacier. Named in honor of California geologist, Bailey Willis, the wall is an almost sheer wall of lava some 3,600 feet (1.097 m) high. Willis explored the north side of the mountain and blazed the first trail to the Carbon Glacier in 1881. He was also influential in securing the passage of the bill that created Mount Rainier National Park.

Thermal Features and Ice Caves

In 1870, active fumaroles were recognized at the summit of Mount Rainier during the first authenticated climb to the top of the volcano (Crandell, 1971). These summit fumaroles, ice caves associated with the fumeroles, and Ohanapecosh Springs are hydrothermal features listed in the Geothermal Steam Act (Barr, 2001). In response to the Geothermal Steam Act, Amendments of 1988, an evaluation of “significant thermal features” in MORA was conducted by the Bureau of Land Management (Korosec, 1989). Thermal features of the park fall into six separate groups:

- Summit thermal area
- Upper- flank thermal areas
- Winthrop Springs
- Paradise Springs
- Longmire Mineral Springs
- Ohanapecosh Hot Springs

Fumeroles at the summit of Mount Rainier are small vents that release steam in an area where the ground temperature is 174° to 185° F (65° to 71° C). The summit thermal area, upper- flank thermal areas, and the Winthrop and Paradise Springs on the lower flanks are thought to be part of a single geothermal system within the edifice of the volcano (Korosec, 1989). Hot acid sulfate- chloride water flows from the upper part of the cone outward toward areas of leakage on the lower flanks (Frank, 2000).

Thermal groundwater flowing from the cone appears to be neutralized by reaction with andesite and cooled by dilution with cold groundwater prior to being discharged into surface waters. Elevated sulfate and chloride were found in two sets of thermal springs near Paradise and Winthrop Glaciers. Cold neutral water with elevated sulfate and chloride discharges was found issuing from Winthrop Glacier (Frank, 2000).

The vented steam at the summit continues to melt ice to form ice caves. The creation of ice caves by the steam vents in an active glacier area represents an unusual geologic feature. The two craters atop the summit of Mount Rainier contain the world’s largest volcanic icecave system (Zimbelman et al., 2000A). In 1997, two active fumeroles were sampled for stable isotopic, gas, and geochemical studies. Data indicate that the hydrothermal system in the edifice of Mount Rainier consists of shallow, meteoric water reservoirs that receive gas and steam from an underlying magmatic system.

In the eastern crater, 2,300 feet (700 m) of caves were mapped in 1997- 1998 (Le Guem et al., 2000). Researchers found the main fumaroles located at the eastern entrance. Very few fumeroles were observed deep within the cave. No sulfur was detected in the gases and CO_2 concentration in the cave atmosphere was close to 300 ppm and around 1 percent in the fumaroles.

155 meters (508 feet) of caves were mapped in the western crater. H_2S concentrations in the cave atmosphere were 2 to 5 ppm, giving it a rotten egg odor, and 0.3 percent CO_2 (Le Guem et al., 2000). Isotope data indicate that meteoric groundwater has diluted the H_2S concentrations, but samples taken from incrustations around a dormant vent record a past history of magmatic components episodically venting at the surface (Zimbelman et al., 2000A).

Ice caves also are usually visible at the base of Paradise, Carbon, and other glaciers. However, these caves formed as a result of glacial meltwater rather than hydrothermal processes.

Longmire Mineral Springs are part of a separate geothermal system. The heat source is probably related to the volcano’s magmatic system at depth and may be fault and/or fracture controlled. This system is of limited extent and has a volume of perhaps three cubic kilometers covering about three square kilometers.

Ohanapecosh Hot Springs consists of 25 springs, ranging from small seeps to small springs. The springs are located near the base of Mount Rainier in the southeast part of the park and like the Longmire Mineral Springs are part of a separate geothermal system, also of limited extent. The springs are indicators of subsurface thermal processes. Temperatures have been reported as high as 122° F (50° C). Flows have been measured between 110- 250 liters per minute.

Yellow- orange to white travertine deposits of unknown thickness underlie parts of a meadow at Longmire and a small area near Ohanapecosh campground (Crandell, 1969B). Travertine is a calcium carbonate mineral and has formed by warm spring water present at both localities.