APPENDIX II

A SHORT HISTORY OF MOUNT RAINIER

Volcanoes were present long before the birth of modern Mount Rainer

Modern Mount Rainier is the most recent of many volcanoes that were once active within the boundaries of Mount Rainier National Park. Those earlier volcanoes are so old that ***erosion*** and mountain building processes have destroyed their original forms. The ***active volcano*** is perched on a highland of peaks and ridges constructed of old volcanic rocks of the ***Ohanapecosh***, ***Stevens Ridge***, and ***Fife's Peak Formations***, and also granites of the ***Tatoosh Pluton*** that formed by ***magmas*** (hot, ***molten*** rock), which cooled slowly and solidified underground. About 40 million years ago, much of what is now western Washington lay beneath the sea. From 36 to 28 million years ago volcanoes, some of which were tall enough to stand above sea level, spread ***lava flows***, ***lahars***, and aprons of coarse volcanic ***sediments*** across the region. Over time these volcanic sediments became cemented into rough, dark ***breccias.*** Breccias and lava flows of the Ohanapecosh Formation can be seen along the hiking trail to Summerland, as the steep slopes of Mount Wow at the start of the West Side Road, and in road cuts and trailside outcrops near Longmire.

At about 26 million years ago the style of ***volcanism*** shifted to highly explosive as hot fast-moving avalanches of rock fragments and volcanic gases that are known as ***pyroclastic flows*** erupted from volcanic ***calderas*** and buried parts of the region. Products of these ***explosive eruptions*** include the light-colored rocks of the Stevens Ridge Formation that are exposed in road cuts along lower Stevens Canyon, as well as near the crest of Backbone Ridge. As the hot pyroclastic flows cooled, the weight of the accumulated material flattened still-hot ***pumice*** lumps into lens-shaped structures visible today in the cliffs of lower Stevens Canyon. Similar pyroclastic rocks, probably from the same eruption, make up Yellowstone Cliffs and the Northern Crags on the north side of the park.

Andesitic lava flows also spread across the region from scattered volcanoes, making up the Fife's Peak Formation (26 to 22 million years ago). These rocks are visible today mainly in the northwest part of the Park, such as in the vicinity of Mowich Lake, and also near the top of Unicorn Peak and extensively to the east of the Park. Many of these magmas failed to erupt and instead spread as subhorizontal sheets (sills) beneath the andesitic volcanoes. Volcanoes were highly active during this period, and the Fifes Peak rocks accumulated to many kilometers (miles) thickness.

Activity last modified: September 5, 2014

Molten rock of the Tatoosh Pluton then rose beneath the surface and punched into the overlying formations from the period of 18 to 14 million years ago. Because they remained deep underground, the Tatoosh magmas cooled slowly, allowing crystals to grow to large sizes, thereby producing several massive bodies of ***granodiorite***. Volcanoes were probably also fed by these underground magma bodies, but evidence for these has been eroded away.

By about 10 million years ago compressional forces along the western margin of the North American Continent began to uplift rocks, eventually leading to today's Cascade Range upon which the active volcanoes sit. As the mountains rose, erosion stripped away many of the overlying ***volcanic rocks*** exposng the Tatoosh Pluton, which supports the Tatoosh Range, a cluster of jagged peaks immediately south of Mount Rainier.

It is unclear if other volcanoes developed following emplacement of the Tatoosh Pluton, as rocks of that age have been eroded away, but an ancestral Mount Rainier grew from about 2 to 1 million years ago, and the modern volcano began to grow about 500,000 years ago.

Mount Rainier grew in alternating stages of high- and low-volume volcanic activity

Modern Mount Rainier volcano grew in four major stages of alternating high- or low-volume eruptive activity, each averaging a little more than 100,000 years duration. During high-volume stages, lava flows traveled as far as 24 kilometers (15 miles) from the ***vent***, and single lava flows had volumes of as much as 8 cubic kilometers (2 cubic miles). During periods of lesser lava output, such as in recent millennia, lava flows rarely extended beyond 8 kilometers (5 miles) from the summit, and individual lava flows had volumes typically of a tenth of a cubic kilometer (0.024 cubic miles) and rarely as much as 1 cubic kilometer (0.24 cubic miles).

Mount Rainier is built by the accumulation of lava flows and rock rubble

The edifice of Mount Rainier volcano was assembled of many individual lava flows erupted over a span of half a million years. The steep faces of the upper volcano have a stair-stepped appearance imparted by alternating cliffs and rubbly slopes. Each cliff exposes the dense interior of a once molten lava flow, and the overlying slope consists of the flow's rubbly top. Successively higher elevation pairs of cliffs and rubbly slopes preserve successively younger lava flows. In addition, about 10 to 20 percent of the rubbly materials are the ***deposits*** of pyroclastic flows. Many hundreds of lava flows are now exposed as thin cliffs high on the ***cone***, whereas thicker and more voluminous lava flows form the large ridges that radiate as far as 24 kilometers (15 miles) from the present summit.

Ice-age glaciers influenced the shape of Mount Rainier and the surrounding landscape

During the ***Pleistocene Epoch*** (1.8 million to 11 thousand years ago), a succession of ***ice ages*** took place. ***Glaciers*** have mantled Mount Rainier for most or all of its 500,000-year lifespan. They covered peaks and filled deep valleys and played an integral role in shaping the volcano. Many lava flows that erupted during ice ages were unable to melt entirely through the thick, valley-filling ice and instead chilled and hardened beside it. With continued eruptions, the lava would skirt the margin of the valley-filling glacier, advancing only where ice was thin or absent. With retreat of the glaciers at the end of the Pleistocene, the valleys emptied of ice, and the lava flows were left perched high on the sides and crests of ridges, much like docks stranded along the former shores of a shrinking lake or reservoir. This process accounts for why lava flows cap many of the ridges radiating from Mount Rainier, instead of filling the deep valleys. Today's glaciers are too small to exert much control on the movement of lava. Instead, eruptions of lava and of pyroclastic flows will melt snow and ice, causing destructive lahars.

Landslides and lahars at Mount Rainier

Mount Rainier is particularly susceptible to lahars and smaller ***debris flows*** because of the abundance of ice, loose volcanic rock, and surface water, and because some slopes have been weakened by the interaction of groundwater and volcanic gases. Most of Mount Rainier's far-traveled lahars formed during eruptions as hot lava and pyroclastic flows mixed with and melted snow and ice, thereby transforming into lahars. Some large lahars have also formed by collapse of hydrothermally weakened upper flanks of the volcano. ***Hydrothermal alteration*** takes place where hot, sulfur-rich volcanic gases encounter groundwater. The sulfur dissolves into the groundwater creating sulfuric acid that attacks and leaches chemical components from the rock. Commonly, the reactions replace much of the rock with clay minerals that are weak and water saturated, thereby promoting failure of the altered parts of the volcano. The presence of abundant soft, wet clay also aids in mobilizing the collapsed material, allowing it to flow like a thick liquid, rather than piling up at the base of the volcano like a rock slide or avalanche.

Figure 1 shows the location of three large lahars from Mount Rainier.

◆ *Osceola Mudflow*

The ***Osceola Mudflow*** of 5,600 years ago was Mount Rainier's signature event during the ***Holocene*** (11,000 years ago to today). (The term lahar is now used more frequently than ***mudflow***.) During a period of eruptions, the volcano's summit and northeast slope slid away, creating a 1.8 kilometer-wide (1 mile-wide) horseshoe-shaped ***crater***, open to the northeast. This massive ***landslide***, which removed 2 to 3 cubic kilometers (0.5 to 0.7 cubic miles) of rock, ice, and debris, quickly transformed into a fast-flowing lahar that traveled through the location of present-day Enumclaw, where it broadened and flowed more slowly toward and into Puget Sound. Since that time, lava flows and other eruptive products refilled much of the crater and formed the present summit cone.

◆ *National Lahar*

The ***National Lahar***, which occurred sometime between 2,200 and 500 years ago, is one of many lahars that formed by the melting of snow and ice during volcanic eruptions. The lahar originated on the south flank of Mount Rainier and flowed down the Nisqually River Valley as far as Puget Sound. It is notable as one of the larger examples of a lahar formed by snow and ice melt during an eruption, the most common cause of lahars on Mount Rainier.

◆ *Electron Mudflow*

The ***Electron Mudflow*** of approximately 500 years ago is remarkable because it may have occurred without an accompanying eruption. The western flank of Mount Rainier collapsed and slid into the Puyallup River Valley, where it transformed into a lahar and flowed 100 kilometers (60 miles) downstream. Scientists continue to speculate about the origin of the landslide. The volcanic flank might have been destabilized by magma that rose into the volcano but failed to reach the surface as an eruption. Alternatively, it may have failed due to earthquake shaking, or it could have collapsed after an extended period of slope creep. The Electron Mudflow reminds us of the possibility that, occasionally, lahars may have noneruption origins and occur with little warning.

◆ *Modern debris flows*

Almost annually, smaller flows similar in character to lahars but unrelated to eruptive activity flow across valley floors within Mount Rainier National Park. These events, known locally simply as debris flows, form by the erosion of unconsolidated rock debris as a result of increases in water from precipitation, glacier melt, and glacier floods. More than 40 of these events have occurred within the past few decades.

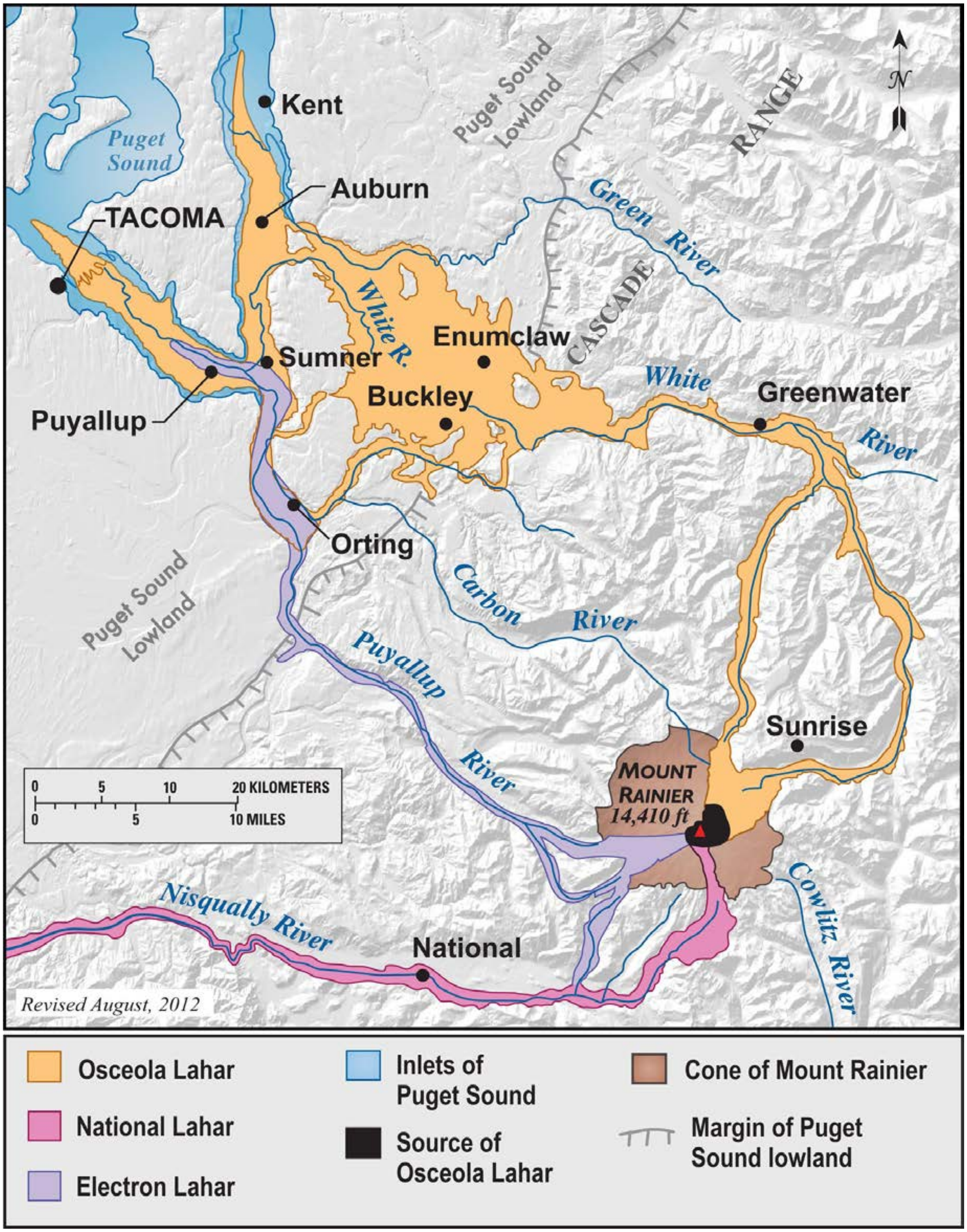

Figure 1*—Map showing location of three lahars from Mount Rainier volcano. Modified from Crandell (1971) and Vallance and Scott (1997).*

Mount Rainier remains an active volcano with potential to erupt again

All evidence suggests that Mount Rainier volcano will continue to erupt, grow, and collapse and will thereby constitute an enduring ***hazard***, as well as a scenic and natural resource that provides recreation, wildlife habitat, and water for drinking and power generation. When Mount Rainier erupts again, volcanic activity may affect people living in the surrounding areas, those visiting Mount Rainier National Park, and potentially those flying overhead. An eruption is likely to be preceded by weeks or months of small earthquakes centered beneath the volcano, by subtle deformation of the volcano, and by increases in volcanic-gas emissions and temperatures. Detection of these natural precursors can allow communities to go to heightened levels of alert and take basic precautions against lahars. Beyond their dependence on volcanic precursors, scientists recognize that lahars, like the Electron Mudflow, can form by slope failure during noneruptive times. This knowledge has motivated scientists to install equipment that detects more subtle movements and a lahar detection system that identifies lahars and warns of their movement before they reach populated areas.

Substantial progress has been made in understanding Mount Rainier's volcanic history and its hazards

Research during the 1980s to today provides an updated view of the history and hazards associated with Mount Rainier, and a challenge to residents, public officials, and scientists to consider seriously the threat of future volcanic activity. Scientists now call Mount Rainier an "active" volcano because of the recency of eruptions in the nineteenth century, its active hydrothermal system, its ongoing seismicity, and its location above a ***subduction zone*** where new magma forms. Mount Rainier has erupted more frequently than was previously known, and links between eruptions and lahars, including flank-collapse lahars, are stronger than had been thought. Collapse hazards are greatest on the west flank because of the presence of hydrothermally altered rock. The likelihood of lahars formed by lava-ice interaction chiefly by pyroclastic flows is higher than was previously supposed. Such eruption-generated lahars threaten all valleys that head on the volcano.

Timeline of Significant Geologic Events at Mount Rainier

See figures 2 and 3 to view Mount Rainier's growth rate and a simplified geologic map.

500,000 to 420,000 years ago

Rapid accumulation of lava

Geologists have strong evidence that the modern Mount Rainier began to erupt atop the deeply eroded remains of an ancestral volcano that had been active 2 to 1 million years ago. Eruptions did not die out entirely between the ancestral and modern volcanoes, but 500,000 years ago marks the beginning of the voluminous and continuous volcanic rock record that we call Mount Rainier; therefore, 500,000 years ago is taken as the onset of eruptions that have built the modern volcano. For the first approximately 80,000 years, the new volcano was highly active, producing a thick apron of pyroclastic flows that are well exposed above Glacier Basin. These pyroclastic flow deposits are preserved as high as Steamboat Prow (3,000 meters or 9,640 feet) where they dip directly away from the present summit, indicating that the new volcano quickly grew to a height similar to that of today. The pyroclastic flow deposits are capped by thick lava flows, such as at Burroughs Mountain, Grand Park, and Old Desolate. The Sunrise visitor facilities sit atop the Burroughs Mountain lava flow, the lower end of which is visible at an elevation of about 1,500 meters (4,800 feet) along the road to Sunrise, where ice-chilled lava columns jut from the tip of the lava flow like whiskers from a chin. The side of the lava flow forms the high cliff above the White River campground.

420,000 to 280,000 years ago

Reduced rate of lava accumulation

Geologists know less about this time period in Mount Rainier's history because infrequent and small eruptions left little evidence within the geologic record. An exception is the Rampart Ridge lava flow, which erupted 380,000 years ago. Visitors get a dramatic view of this ridge from Longmire, where they observe it from the valley floor once filled by glacier ice. Because of infrequent eruptions, the upper mountain was probably eroded substantially during this time and greatly reduced in height.

280,000 to 160,000 years ago
Rapid Accumulation of lava

Eruption rates increased again around 280,000 years ago and persisted to about 180,000 years ago, as shown by extensive lava flows on the flanks of Mount Rainier, including on the west at St. Andrews Park, Klapatche Point, and Sunset Park, and on the east at Meany Crest. The volcano grew to perhaps its greatest height, as shown by 200,000-year-old rocks preserved high on the Mowich Face on the volcano's upper west flank. So much magma passed though the volcano that its upper west and east flanks split open. Magma poured through these cracks, feeding large lava flows from flank vents. Some of the magma remained within the cracks where it eventually froze and is preserved as ***dikes***. These magma-filled cracks and dikes also provided heat and acidic volcanic gases that altered and weakened the upper west and east flanks of the volcano, setting the stage for the much younger collapses that spawned the Osceola and Electron Mudflows.

160,000 to 40,000 years ago
Reduced eruptions accompanied by erosion of the upper mountain

Eruption rates waned gradually after 180,000 years ago, with dikes and vents on the upper east side of Mount Rainier feeding the lava flows that constructed Little Tahoma, lending an oblong shape to the volcano. At about 105,000 years ago, new vents opened on the lower northwest flank of the volcano and lava flows of ***basaltic andesite*** (hotter, more fluid magmas than typical for Mount Rainier) spread across the Spray Park and Mist Park areas from cinder cones now preserved as Echo and Observation Rocks. Another lava type atypical for Mount Rainier erupted at 130,000 years ago from a vent well to the north of the volcano at Windy Gap and flowed against ice filling the present Carbon River Valley, producing the lava flow of Bee Flat. These north and northwest flank vents were probably fed from great depth, rather than laterally from the nearby Mount Rainier magmatic plumbing system.

With reduced eruption rates, erosion again incised the upper edifice, apparently removing much of the upper north and south flanks and reducing the summit elevation. There were some other notable constructional events, which produced features that we see today. An eruption 102,000 years ago produced a lava flow over which Comet Falls descends. A pyroclastic flow filled the headwaters of Kautz Creek. A lava flow that erupted about 91,000 years ago now caps Mazama Ridge, supports The Bench, and descends into Stevens Canyon.

40,000 to 15,000 years ago
Reconstruction of the upper mountain

Eruption rates increased again about 40,000 years ago, although not to the degree of the earlier high-effusion stages. With the exceptions of the Mowich Face and Little Tahoma, most of the upper headwalls and ridges on Mount Rainier were constructed during the period 40,000 to (roughly) 15,000 years ago, with many age determinations clustering near 40,000 years. These relatively youthful lava flows include those exposed on Liberty Ridge, Willis Wall, upper Curtis Ridge, Gibraltar Rock, Wapowety Cleaver, Success Cleaver, and Tahoma Cleaver, as well as the Tahoma Glacier Headwall. The only flank lava flow from this time is that of Ricksecker Point (40,000 years ago) that also supports Narada Falls. The Ricksecker Point lava flow was important for developing understanding that glaciers directed the courses of lava flows at Mount Rainier. Canyons 250 meters (800 feet) deep flank Ricksecker Point on the north and south, but 40,000 years is too brief a time to excavate to such depths by erosion. Impoundment of the lava flow against thick glaciers that filled the valleys to the north and south, followed by emptying of the canyons during ice retreat, provides a ready explanation for the great depths of the flanking canyons despite the relative youth of the lava flow. This stage of reconstruction of upper Mount Rainier overlaps the most recent period of thick glaciers formed during the most recent major ice age that peaked at 20,000 years ago. The rough ridge and headwall of the upper mountain results from thin lava flows encountering thick ice, as well as to simultaneous rapid glacial erosion and lava effusion. Growth of upper Mount Rainier is also roughly synchronous with growth of upper Mount Adams (less than 30,000 years old), as well as the beginning of growth of present-day Mount St. Helens (earlier volcanoes were present at that location).

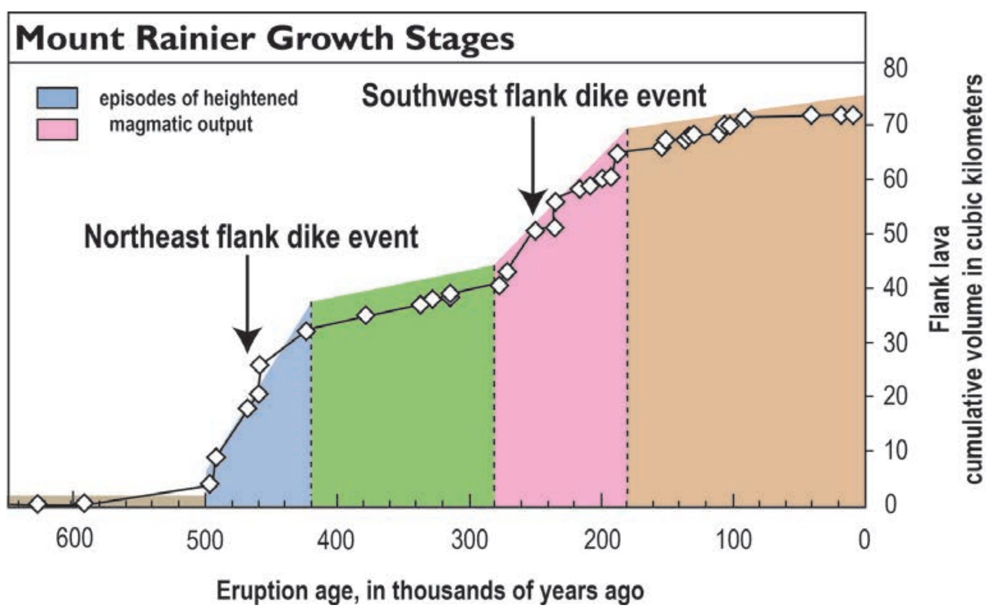

Figure 2—*Graph of Mount Rainier growth stages showing times of heightened magmatic output and times of dike emplacement. Each symbol represents a mapped and dated flow or flow group. Adapted from Sisson,Vallance, and Pringle (2001).*

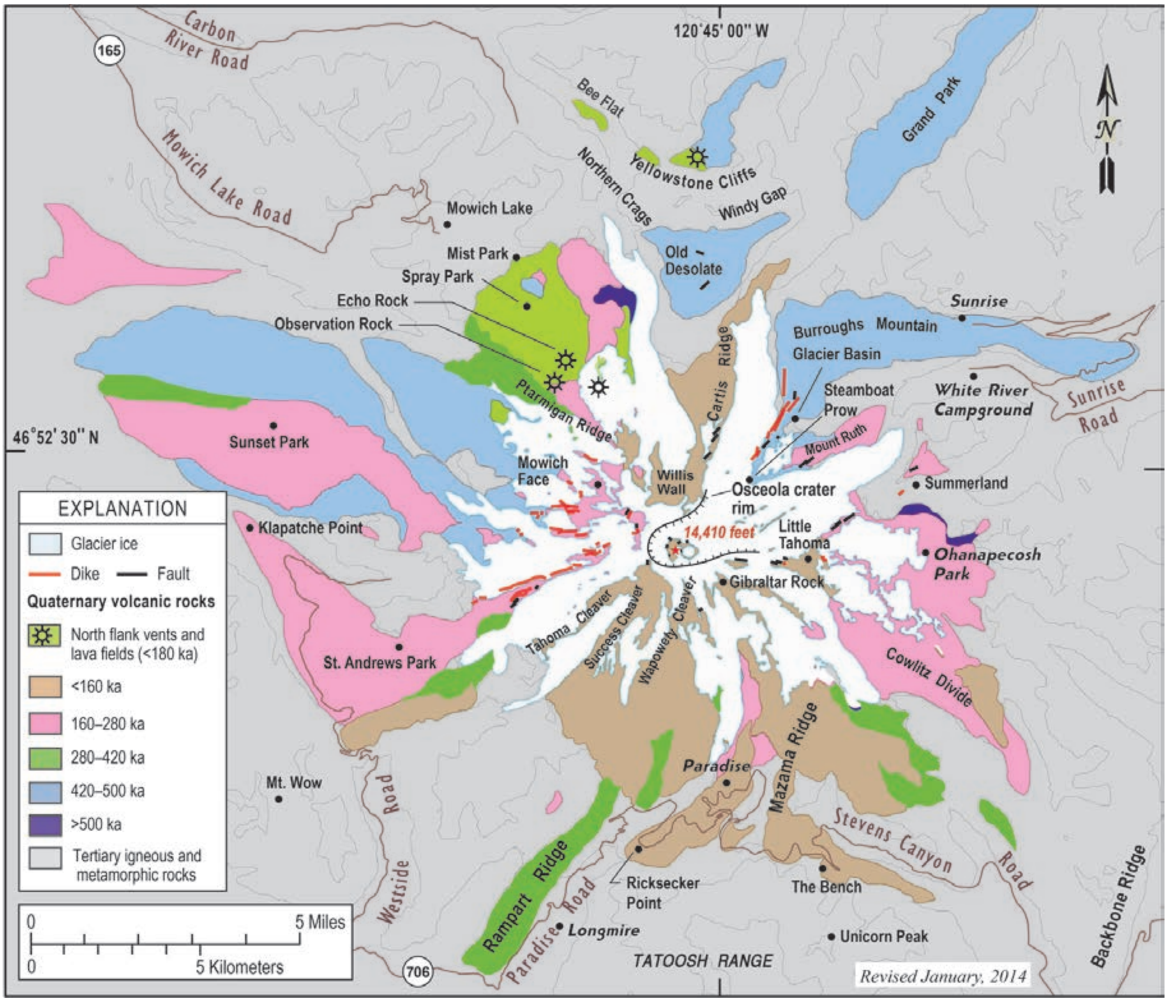

Figure 3*—Schematic map showing simplified geology of Mount Rainier volcano, Ka is thousands of years before present. Adapted from Sisson, Vallance, and Pringle (2001).*

A Short History of Mount Rainier Volcano-continued . . .

Holocene (post-last ice age) eruptive periods

More detail is known about the recent part of the geologic record because it post-dates extensive ***glaciation,*** and therefore the products are well preserved. Various ***eruptive periods*** for Mount Rainier have been identified based on temporal clustering of ***tephra*** deposits, in most cases accompanied by numerous lahars. The periods are mostly named after locations where their deposits are particularly well preserved and complete. Six eruptive periods are noted between 11,000 years ago and the present. Each lasted perhaps a few years or for as long as more than one thousand years. See table 1 summary of notable Holocene events at Mount Rainier, 11,000 years ago to present.

The Holocene eruptive periods for Mount Rainier were determined from studies of volcanic ***ash*** layers on the volcano, which at this writing, remain in progress. Scientists often derive the age of ash layers by measuring the age of wood within or adjacent to them. Our knowledge of these eruptive period ages will become more precise as additional studies are done.

Sunrise eruptive period (approximately 11,000 years ago)

An eruption deposited volcanic ash (Layer R) across the northeast part of Mount Rainier National Park. One lahar, apparently of landslide origin, moved across Van Trump Park.

Cowlitz Park eruptive period (7,400 to 6,700 years ago)

Eruptions produced seven tephra layers and several lahars. Pyroclastic flows across snow and ice probably caused two or three lahars, at least one of which traveled as far as the Puget Sound lowland 70 kilometers (43 miles) downstream. About 7,300 years ago a collapse caused a lahar that spilled over the Paradise Ridge and moved as far as Reflection Lakes. Reflection Lakes exist within the low areas of this lahar.

Osceola eruptive period (5,600 to 4,500 years ago)

Early in this eruptive period, the Paradise Lahar swept down Mount Rainier's south side along the Nisqually River as far as the village of National. Later, explosive eruptions (***phreatic*** and ***phreatomagmatic eruptions***) triggered an edifice collapse that included the summit of the volcano and northeast flank. The 4 cubic kilometer (1 cubic mile) Osceola Mudflow evolved from this avalanche of altered rock and flowed down the White River Valley, across the Puget Sound lowland into Puget Sound, and at least 20 kilometers (12.4 miles) underwater to the present sites of Tacoma and the Seattle suburb of Kent. The Paradise Lahar, now recognized as the southern part of the Osceola Mudflow, swept down the Nisqually River Valley as far as the community of National. Eruption of several tephra layers suggests that a period of cone building ensued.

A Short History of Mount Rainier Volcano-continued . . .

Summerland eruptive period (2,700 to 2,000 years ago)

About 2,700 years ago Mount Rainier began to erupt again, producing tephra, lahars, and a landslide-induced lahar called the ***Round Pass Mudflow***. A sequence of tephra falls, pyroclastic flows, and lahars followed, indicating continued eruptions separated by time intervals ranging from several tens to hundreds of years. The largest Holocene tephra eruption (Layer C: 0.1 to 0.2 cubic kilometers or 0.02 to 0.04 cubic miles) occurred about 2,200 years ago. It covers areas near Sunrise visitor center, as well as Burroughs Mountain. Summerland period lava flows descended from the summit and underlie much of the upper Emmons and Winthrop Glaciers. The upper part of Camp Schurman sits atop lava erupted from the summit at this time. Summerland lahars and associated sediment accumulated to depths of several meters thickness at sites as far downstream as Auburn. By the end of the Summerland eruptive period the summit of Mount Rainier had grown to its present form and altitude.

Twin Creeks eruptive period (approximately 1,500 years ago)

Several thin ash deposits restricted to subalpine meadows and far-traveled lahars of the ***Twin Creeks assemblage*** show that small eruptions took place about 1,500 years ago. Although these events involved the eruption of new magma, no lava flows were produced. In some literature, considered part of the ***Deadman Flats assemblage.***

Fryingpan Creek eruptive episode (1,100 to 1,000 years ago)

About 1,100 years ago, one or possibly two lahars flowed down the White River as far as Auburn. These lahars may have been generated as pyroclastic flows descended the Emmons and Winthrop Glacier and incorporated and melted snow and ice. Reworking of the lahar sediment caused extensive aggradation of the Duwamish River Valley as far as Puget Sound and the southernmost Seattle suburbs. No lava flows were produced.

Electron Mudflow (around A.D. 1503)

About A.D. 1503, an avalanche of hydrothermally altered rock from the west side of Mount Rainier caused a lahar (Electron Mudflow: (0.26 cubic kilometers or 0.06 cubic miles) that swept down the Puyallup drainage at least as far as Sumner. It is not known whether an eruption or some other event triggered the lahar. Other lahars descended the Nisqually and White River drainages at about this time.

New ideas about mid-nineteenth century eruptions—The X-tephra

Early studies of Mount Rainier's eruptive history report the presence of sparse tephra locally scattered on young ***glacial moraines***. This was named the X-tephra and was interpreted as a product of an eruption of Mount Rainier dating between A.D. 1820 and 1854. More recent study shows that this material is the 2,200-year-old tephra from the Summerland Eruptive Period. In some localities it was transported and redeposited on younger glacial moraines by snow avalanches, and in other areas it was incompletely eroded by late Holocene glacial advances and therefore lies within the perimeter of younger glacial deposits. The X-tephra therefore appears not to be a true eruption deposit.

1840s through 1890s—Steam Explosions

Occasional steam blasts at the summit of Mount Rainier were reported by early pioneers in the Puget Sound region. The most well documented report came in the winter of 1894–95, when many residents of Seattle saw ***explosions*** of steam and "black smoke" (accepted today as volcanic ash) rising from the summit. There is no evidence that new magma accompanied these explosions, which might have been caused by interactions of hot rock and water. Although there may have been small eruptions of Mount Rainier during the nineteenth century, no physical evidence remains as confirmation.

Summary of Notable Events—11,000 Years ago to present

Eruptive Period	Age or Date	Event	
Historic activity	A.D. 1980s to present	Several dozen debris flows in river valleys that head on Mount Rainier	
	A.D. 1963	Rock fall avalanche from Little Tahoma Peak	
	A.D. 1947	Debris flow and runout flow of glacial-outburst origin in Kautz Creek	
	A.D. 1930s to 1950s	Multiple debris flows in Nisqually River Valley	
	A.D. 1910 to 1927	Rock avalanche on Tahoma Glacier	
	A.D. 1894 to 1895	Reports of small steam and ash eruptions at summit	
	500 years ago	Rock avalanche-induced Electron Mudflow in Puyallup/Nisqually River Valleys; no documented association with volcanic eruptions	National Lahar in Nisqually River Valley sometime between 2,200 and 500 years ago
Fryingpan Creek eruptive episode	1,100 to 1,000 years ago	Lahar down Puyallup River at least as far as its confluence with Mowich River	
		Tephra and lahars in White River Valley as far as Kautz Creek	
Twin Creeks eruptive episode (Deadman Flats)	1,500 years ago	Tephras and lahars in valleys of the White River and Kautz Creek	
Summerland eruptive period	2,000 years ago	Lava flows formed summit cone, Columbia Crest	
	2,200 years ago	Eruption of Layer C tephra	
	2,200 to 2,600 years ago	Lahar in Nisqually River Valley deposits sandy layers	
	2,400 to 2,500 years ago	Eruption of block-and-ash flow in Puyallup River Valley; Eruption of tephra layers	
	2,600 years ago	Lahar-Round Pass mudflow descended Puyallup valley to Puget Sound lowland. Part of it descended Tahoma Creek and the Nisqually River	
	2,200 to 2,700 years ago	Multiple lahars in White River Valley	
Osceola eruptive period	4,500 years ago	Eruption of tephra layer B	
	4,700 years ago	Eruption of tephra layer H	
	5,600 years ago	Lahar-Osceola Mudflow in White River's main branch and West Fork extended to Puget Sound lowland. Eruption of tephra layer F; Paradise Lahar (part of the Osceola Mudflow) in Nisqually River Valley, extended as far as the community of National	
	>5,600 years ago	Eruption of tephra layer S	
Cowlitz eruptive period	6,700 years ago	Eruption of tephra layers N and D	
	7,400 to 7,200 years ago	Eruption of volcanic bomb-bearing rocks and lahars in White River Valley	
	7,400 to 7,200 years ago	Rock avalanche-induced lahar down the Nisqually River and at Reflection Lakes	
	7,400 to 7,200 years ago	Eruption of tephra layers L and A	
Sunrise eruptive period	11,000 years ago	Eruption of tephra layers L and R	

***Table 1**—Summary of notable events at Mount Rainier, approximately 11,000 years ago to present.*

Author Note

The authors of this section of GIP 19 acknowledge the valuable input to this text by USGS researchers James Vallance and Tom Sisson. More precise ages and information about eruptive history will be published and posted on USGS Web sites as new evidence emerges.

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