APPENDIX III

Journey Back in Time

A Mount Rainier Geological Field Trip Guide for Teachers

Nisqually Entrance to Paradise

By Carolyn Driedger with contributions by Tom Sisson and Jim Vallance

"To a person uninstructed in Natural History, his country or sea-side stroll is like a walk through a gallery filled with wonderful works of art, nine-tenths of which have their faces turned to the wall."
Thomas Henry Huxley, *Aphorisms and Reflections*

Activity last modified: September 7, 2014

Teacher Instructions

Overview:

Journey Back in Time—A Mount Rainier Geological Field-Trip Guide for Teachers provides background information, suggested activities, and itinerary for a geology-oriented field trip to the southwest side of Mount Rainier National Park. This field-trip guide and its companion geologic overview, **A Short History of Mount Rainier**, are appendices in **Living with a Volcano in Your Backyard—an Educator's Guide with Emphasis on Mount Rainier** (hereafter called the Educator's Guide). This field-trip guide can be used in conjunction with classroom activities within the parent document.

Journey Back in Time assumes that your group will arrive through the Nisqually Entrance at the southwestern corner of the park, the only year-round access point, and will end at the Paradise visitor facilities. This guide describes stops at Kautz Creek, Longmire, Ricksecker Point, and Paradise. Sunshine Point, Tahoma Creek, Christine Falls, and the Glacier Bridge are places to drive past slowly for through-the-window observations and discussion. Use this field-trip guide to plan your trip. Although time limitations prohibit most people from exploring every stop and trail, this guide provides a variety of options. Consider use of the discussion questions and activities to promote observations and to maintain focus on key concepts. You might opt to tailor the questions to your group's abilities. Check for updates and accompanying materials in the "For Teachers" pages of the Mount Rainier National Park Web site http://www.nps.gov/mora/.

Planning your field trip to Mount Rainier National Park:

Read through this guide to determine which stops, activities and experiments work best for your group. Staff at Mount Rainier National Park run an Education Center at Tahoma Woods administrative facility, three miles west of Ashford, Washington, and can help arrange your visit, ***including fee waivers for educational groups***. Reach them at (360) 569-2211. Weather and road conditions should be a primary consideration for the timing of your trip. Summer and fall conditions allow maximum travel on roads and trails. The National Park Service strives to keep the road to Paradise plowed in winter and offers winter snowshoe walks. Uneven surfaces on trails and slopes can make trips challenging at any time of the year. Before making commitments, give careful consideration to the physical abilities of your group. Find directions to the park, current weather and travel conditions, and additional trip planning support at the park Web site. ***The authors strongly recommend a dry run of the proposed trip prior to your scheduled departure.***

Supporting activities:

Field trips are greatly enhanced when preceded and followed by associated classroom activities. Encourage student interest by conducting any of the activities in the Educator's Guide. The activity **Planning Your Trip to Mount Rainier National Park** provides pages for student planning before the field trip and reserves space for photographs and drawings. It includes several quick outdoor science experiments for stops at Kautz Creek, Longmire, and Paradise and along the Nisqually Vista, Glacier Vista, and Panorama Point Trails.

Key concepts addressed on this field trip:

During your journey within the park, you will find abundant evidence that supports several overarching geological principles. The authors base the scope of field trip descriptions and guided questions on geologic features that best support successful student observations. During your field trip, encourage discussion of the following principles.

- Ongoing geologic change is abundant and observable at Mount Rainier National Park. No two trips to Mount Rainier yield identical observations.
- Processes in the rock and water cycles, as studied in many classrooms, are manifested throughout the year at Mount Rainier National Park—snowfall, snowmelt, glacier motion, river flow, flooding, debris flows, rock weathering, erosion and deposition, rock fall, and hot springs and geothermal steaming from the volcano's warm interior.
- Volcanic and glacial processes are the principal forces that shape the landscape. The interaction of these forces created much of the landscape that we see today**.**
- Volcanic processes have rearranged the landscape intermittently. Scientific evidence abounds for ancient volcanic activity before the birth of Mount Rainier and for future volcanic eruptions.
- Geologic processes, past and present, influence the lives of humans, animals and plant life at Mount Rainier National Park.

For additional information:

Find more in-depth information about the geologic story of Mount Rainier, in the *Roadside Geology of Mount Rainier National Park and Vicinity,* Department of Natural Resources Information Circular 107, by Patrick T. Pringle, available from the Washington Department of Printing and some retail stores.

Student perceptions of volcanic activity:

Students may voice concern for their safety while visiting volcanic Mount Rainier National Park. You can lessen their concern by discussing how Mount Rainier is like a person sleeping. The mountain is presently at rest but will reawaken some day. The mountain cannot erupt without first displaying some symptoms of awakening. Explain to them that scientists are watching for evidence of rising magma, such as volcanic earthquakes, gas releases, and changes to surface elevation. These symptoms are evident for days to months or more preceding an eruption. When scientists detect these signs of reawakening, they will notify local and federal officials and the public.

The Route to the Park

Logistics:

Find driving directions to the Nisqually Entrance at the Mount Rainier National Park Web site: http://www.nps.gov/mora/

Features of Interest:

1. Glaciated Puget Sound lowlands
2. Nisqually River
3. Evidence of past lahars
4. Cascade Range

Figure 1— *Mount Rainier seen on approach, near National, Washington. USGS photo by C. Driedger.*

Background:

- ***Glaciers and volcanoes are the principal shapers of local terrain.***
  On at least six occasions between 1.8 million and 11,000 years ago lobes of glacier ice flowed southward from Canada to the Puget Sound lowland and filled the region between the Olympic Mountains and Cascade Range. Each ice lobe had a similar routine, hauling rocks southward, melting, and dropping rock debris. Beneath the ice, water flowing at high pressure carved broad valleys now flooded by Puget Sound and Lake Washington or sites of major rivers. Parts of Seattle, Tacoma, Everett, Olympia, and Bellevue sit high on thick stacks of compacted glacial rock debris called till. Renton, Puyallup, Kent, Auburn, Sumner, and Orting were built on valley floors. Enter, Mount Rainier! On perhaps hundreds of occasions, lahars (volcanic mudflows) rushed down valleys, and spread mud and boulders broadly, and raised the elevation of valley floors. The same valleys are at risk from lahars today.

- ***LaGrande to Nisqually Entrance—Follow the Nisqually River to its source on Mount Rainier.***
  The Nisqually River drains water from the south and southwest flanks of Mount Rainier. The route between LaGrande and Nisqually Entrance affords glimpses of the many uses of this river—hydropower generation, recreation, and fish and wildlife habitat. Fine sediments create the water's milky color that is common during summer and autumn. The abundant sediment load of sand and gravel causes braiding of the river channel. The Nisqually River Glacier extended as far as the west end of Ashford as recently as between 22,000 to 15,000 years ago.

- ***Look for evidence of past lahars (volcanic mudflows).***
  Lahars (volcanic mudflows) sped down the Nisqually River Valley on multiple occasions in the past. In Ashford, look for tan-colored deposits of the 5,600 year old Paradise Lahar at the restaurant parking lot across from the general store. Find more mounds perhaps from the Paradise Lahar on both sides of the road about 1 kilometer (0.6 mile) east of Ashford. You will learn more about this lahar later.

- ***Mount Rainier in the distance east of Ashford.***
  During clear weather, Ashford is an excellent location to view the landslide and glacier-scarred west flank of Mount Rainier. About A.D. 1502 or 1503, the mountain's west side slid away and rushed down the Puyallup River Valley as the Electron Mudflow. Scientists obtain these precise ages by using a combination of radiocarbon dating and tree ring studies on wood from buried trees.

Nisqually Entrance and Sunshine Point

Mile 0 & Mile 0.4

Logistics: Slow Pass

Visitors get a view of the Nisqually River during a "slow pass" along the river. Please do not stop the bus.

Features of Interest:

1. Close-up view of Nisqually River
2. Damage from the 2006 flood

Figure 2— *Nisqually River near Sunshine Point, December 2006. USGS photo by C. Driedger.*

Background:

- ***Floods of 2006 had a devastating effect on park facilities.***
  In a place as wet as western Washington, it is difficult to imagine that a few days of rainfall in 2006 led to floods so devastating that Mount Rainier National Park was forced to close for 6 months. All over the park, rivers and streams flowed out of their channels. The resulting floods caused destruction unlike anything the park had experienced in its 108-year history. The National Park Service estimates that damage to roads, trails, campgrounds, and buildings exceeded $36 million.

  On November 5, 2006, a steady rain began to fall on soils already saturated from previous precipitation. The rain continued, and by November 7 nearly 46 centimeters (18 inches) of rain had fallen at Paradise. Before the floods, a forest stood between the road and the river. Flood waters in the swollen river eroded the embankment, uprooted the trees, and collapsed the road and utility lines. River water swept away most of Sunshine Point and its campground and picnic area (now permanently closed). Approximately 0.3 kilometers (0.2 mile) east of the entrance station, visitors travel over the repaired road and get a stunning and close-up view of the Nisqually River.

  Evidence of the flood is visible in many river valleys around the park. The bridge over Tahoma Creek was buried by boulders and sediment. At Kautz Creek, the old channel was filled with boulders and sediment, and the creek cut a new channel to the east and left the old channel to the west nearly dry.

Discussion questions for drive to Longmire:

◆ Your entry into Mount Rainier National Park is an appropriate time to begin discussions and student observations about the rock cycle, water cycle, ongoing landform changes, the history of repeated volcanism and how these processes affect living things. Encourage discussion about how water and ice modify the landscape. Ask students for evidence that they are approaching a volcano. Ask students how the river might affect animal and plant ecosystems within the park and beyond.

Tahoma Creek Mile 1.2

Safety note: A word of caution about debris flows—Be alert.
Debris flows occur most often during periods of hot weather in late summer and during severe rainstorms in autumn and early winter. If you are near a stream and hear a roaring sound coming from up valley, or note a rapid rise in water level, move quickly up the stream embankment, away from the stream channel, and to higher ground. Do not try to escape by moving downstream; debris flows move faster than you can run on a streambed of boulders. Observe National Park Service regulations provided for your safety. Here, as in most areas in other national parks, natural processes such as floods and debris flows are allowed to occur without human intervention.

Logistics: Slow Pass

Catch a brief glimpse of Tahoma Creek. Please do not stop the bus on the bridge, but have the driver slow down and put on emergency flashers while crossing.

Features of Interest:

1. Glacial flour
2. Debris flow history of Tahoma Creek

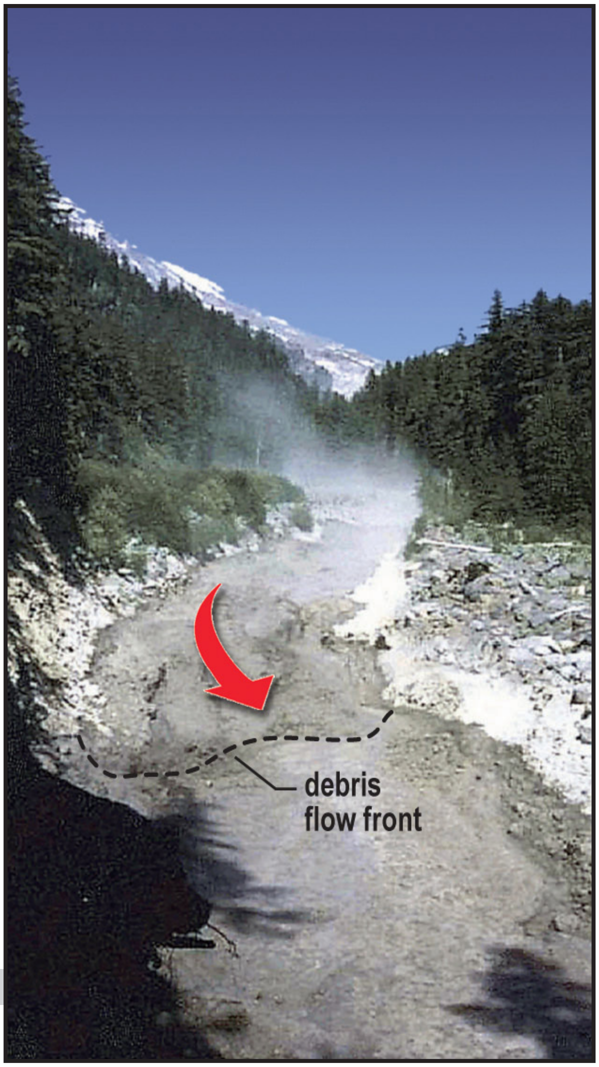


Figure 3— *Debris flow on Tahoma Creek, July 26, 1986. Wave front near the tip of the arrow was approximately 3 meters (10 feet) in height. USGS photograph by G.G. Parker.*

Background:

- ***The scoop on debris flows:***
  Debris flows are masses of water, rock, vegetation, and mud that surge down valleys, leaving in their wake splintered trees and damaged structures. Traveling at speeds of 30+ kilometers per hour (20+ miles per hour), and loaded with boulders and mud, debris flows resemble flows of wet concrete. You cannot outrun a debris flow. Debris flows form by the mixing of loose rock with the excessive stream flow caused by intense rain or snowmelt or from sudden glacier outburst floods. The abundance of surface water and loose volcanic rock encourage the formation of debris flows almost annually within the park. In valleys, debris flows are one of the most common and efficient agents of landscape change. Debris flows form in remote areas nearly inaccessible to people but may move rapidly downstream into areas frequented by visitors.

- ***What is the significance of debris flows on Tahoma Creek?:***
  At least 27 debris flows rushed down the valley of Tahoma Creek between 1985 and today—more than in any other valley within the park. Since 1967, debris flows in the Tahoma Creek Valley have transported more than 10 million cubic meters (350 million cubic feet) of sediment, damaging roads and facilities upstream of the highway bridge. (That amount of sediment is enough to fill in 4,000 Olympic-size swimming pools!) Sediment has filled the river bed and raised the level of water so much that flooding threatens the surrounding area. Park employees periodically use bulldozers to extract excess sediment from the channel to keep the water and debris at a safe distance below the bridge. Why Tahoma Creek? South Tahoma Glacier melted drastically during the second half of the twentieth century and retreated upvalley, exposing a lot of loose sediment to the erosional powers of stream water.

- ***Glacial flour:***
  At the bed of a glacier, ice-bound rocks grind against bedrock and create a fine-grained rock powder called glacial flour. When glacial flour is combined with stream water, the gray-colored water is known as glacial milk. Glaciers move faster and grind more rock to powder in summer than in winter. Because of this, you might observe clear water in the glacial rivers around Mount Rainier.

Discussion questions for drive to Longmire:

◆ While driving slowly across the bridge over Tahoma Creek (there is no safe place to stop for students to get out here), you will be able to see the abundance of cobbles and boulders in the stream channel. Ask them to suggest hypotheses about what produces the current stream color and how the color might change through the seasons. Encourage students to consider processes that are part of the rock cycle and the water cycle. What evidence do they see of recent change? Encourage students to consider processes that are part of the rock cycle and the water cycle. What evidence do they see of recent change?

Kautz Creek Debris Flow Viewpoint

Mile 3.4

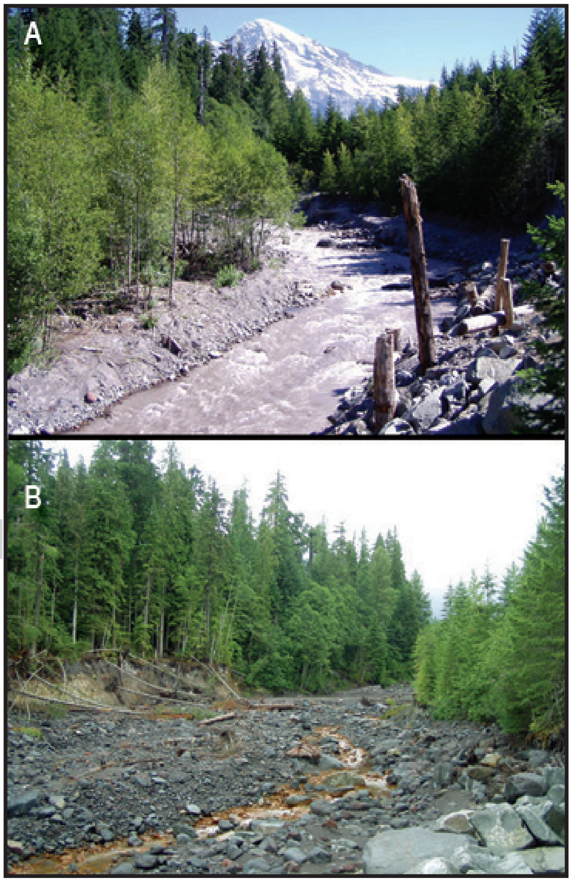
Logistics: 1.5 hours

30 minutes for viewpoint;
1 hour with **Lahar in a Jar** activity

Park in the lot on the south side of the highway. Observe the effects of debris flows safely by following the fully accessible trail to the viewpoint. Use care crossing the highway. Note: Tables in the picnic area are the best location for discussion and conducting the **Lahar in a Jar** activity found in the Educator's Guide.

Features of Interest:

1. Terrain built by 1947 Kautz Creek debris flow
2. Channel changes at Kautz Creek during the November 2006 flood
3. Deposits from previous debris flows in stream embankment
4. On this route, first in-park view of Mount Rainier



***Figures 4A and B**—Kautz Creek in 2001 and 2006, after rerouting of the stream by debris flows. USGS photos by C. Driedger.*

Background:

- ***On October 2–3, 1947, a debris flow swept down the Kautz Creek Valley and covered the road with 25 to 30 feet (7 to 9 meters) of mud, rocks, and tree debris. From the west, the road climbs uphill on to the debris-flow deposit.***
  This debris flow originated at Kautz Glacier and resulted from a combination of intense rainfall (15 centimeters or about 6 inches) and a glacier outburst flood—a sudden release of water trapped within the glacier. A 2-kilometer-long (1.2 miles) segment of the lower Kautz Glacier was washed away by floodwaters. Eyewitnesses report that this debris flow had the consistency of wet concrete and carried chunks of ice, trees, and boulders as large as recreational vehicles. Note the tree snags. The best preserved trees are the tall pointed snags of western red cedar. All the living trees are younger than this debris flow event.

- ***Floods of 2006 change the channel of Kautz Creek.***
  During the floods of November 5 and 7, 2006, floods again modified the Kautz Creek Valley. A debris flow 1.6 kilometers (1 mile) upstream blocked the channel and forced Kautz Creek to flow through the forest and establish a new course approximately 200 meters (650 feet) east of the bridge. The flood undermined the road, damaged the buried power line, and caused severe erosion to nearby park maintenance facilities.

- ***Prognosis for the future:***

  We can expect that future floods and debris flows will change the course of Kautz Creek and, on occasion, will necessitate road closures. The buildup of rock debris in the streambed, known as aggradation, raises the water level in stream channels. This action threatens the long-term safety of road and building facilities in river valleys around the park.

Discussion questions for Kautz Creek viewpoint or parking lot:

General observations:

- ◆ You passed through old-growth forest on your way to Kautz Creek. Are trees near the Kautz Creek parking lot similar or different in age? ***Trees near the parking lot are smaller and younger.***
- ◆ What process(es) near the creek could have killed old growth trees? ***Burial by rock debris from flooding and debris flows or disease (best specific answer is the debris flow of 1947).***
- ◆ What processes have transported fresh rock debris to the area? ***Debris flows, and stream transport.***
- ◆ List several characteristics of Mount Rainier's environment that make it prone to debris flows and lahars. ***Abundance of loose rock from glacial and volcanic actions, abundance of water from precipitation and snowmelt, rapid changes in stream discharge, steep water-saturated stream banks, exposure of rock debris to erosion after melting of snow and ice.***

Rock and water cycles:

- ◆ Name some parts of the rock cycle and the water cycle that are evident here. ***Several stages of the rock cycle are in evidence—rocks intact within the face of Mount Rainier, rock layers in the river embankment, rocks in the riverbed, and fine-grained sediment carried in river water. Evidence of the hydrologic cycle include stream flow, flooding, deposits from past debris flow activity, and glacier activity upstream.***

Kautz Creek and the local ecosystem:

- ◆ Explore how the presence of debris flows and floods affected human, animal, and plant life in the vicinity of Kautz Creek. ***Repeated floods and debris flows have destroyed forest habitat for plants and animals and forced them to adapt. On multiple occasions, park employees rerouted the road, dredged channels, and created new highway drainage systems.***

The picnic tables are an appropriate place to conduct the **Lahar in a Jar** activity. The activity is found in the Educator's Guide described on page 2 of this appendix.

Longmire

Mile 6.3

Logistics: 1–2 hours

Plan to use 1 hour for Longmire/Trail of Shadows walk;
30 minutes for Longmire Rocks walk;
30 minutes for the Nisqually River walk.

On arrival at Longmire, turn right into the parking lot (including spaces for buses) behind the National Park Inn. Plan to take one, two, or all three walks described here. ***Obtain a current map of trails at the Longmire Museum.***

Features of Interest:

1. View of Mount Rainier
2. Longmire Meadows and Trail of the Shadows with views of the warm mineral springs and the massive Rampart Ridge lava flow
3. Intrusive rocks used in buildings and bordering paths
4. Nisqually River road bridge

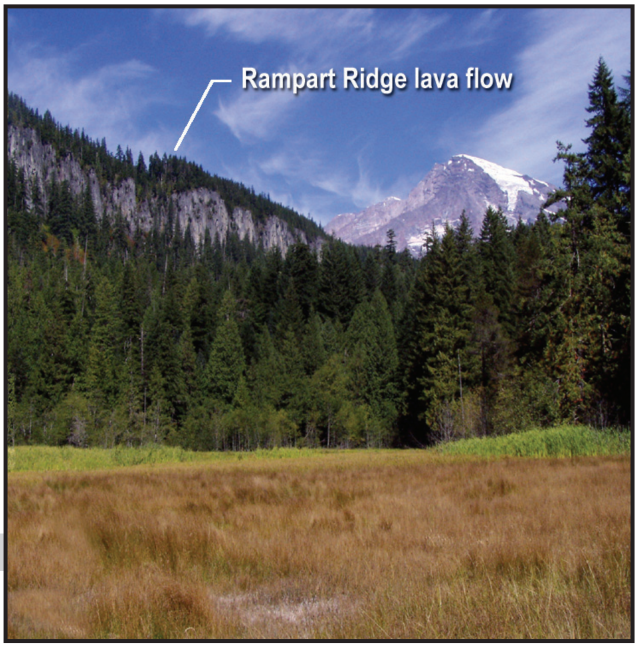


Figure 5*—Longmire meadow and springs flanked by Rampart Ridge lava flow. USGS photo by C. Driedger.*

Background:

- ***Longmire is a grand setting for viewing Mount Rainier and related volcanic landforms.*** The story of James Longmire serves as a reminder of the natural human attraction to volcanic areas. In the 1880s, pioneer James Longmire established a homestead, hotel, and mineral springs resort here. At its height of popularity, thousands of visitors soaked in mineral waters. Later, the National Park Service built its park headquarters and a small natural history museum here, and the National Park Inn was opened. Today, only remnants of James Longmire's resort survive alongside some reconstructions. The museum and park headquarters building remain, although official headquarters are situated outside of the park. The historic gas station houses an exhibit that describes early transportation at the park. All of the park community of Longmire is now designated as a National Historic Landmark District. Longmire is a popular stop for today's visitors because of its trails, exhibits, gift shop, and lodge. It is the last field trip stop with restroom access before the Paradise visitor facilities.

The visit to Longmire can be a practical review for students who have completed the classroom activities **Fire and Ice** and **Magma Mash** in the Educator's Guide.

Longmire Area Trails—Mount Rainier National Park

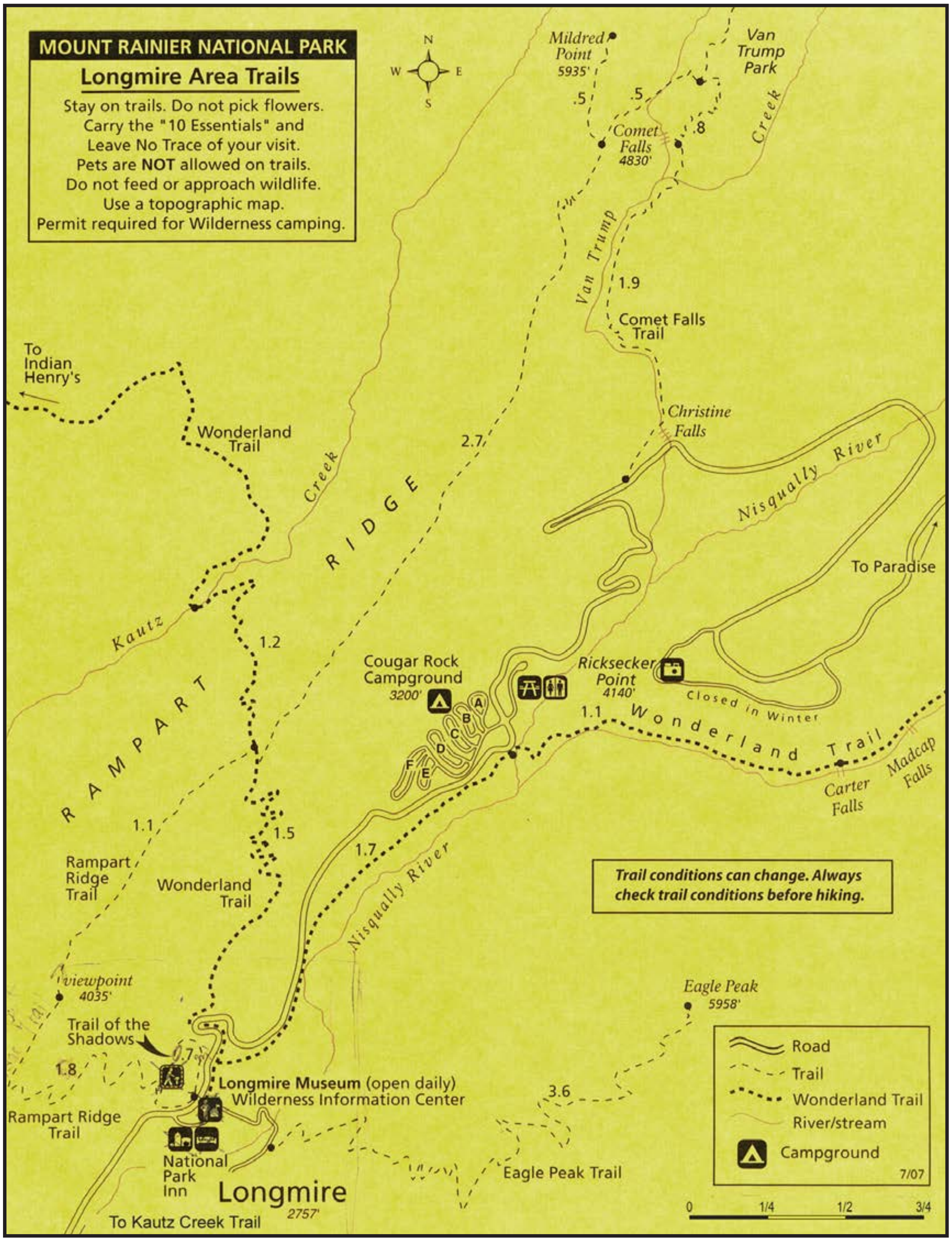


Figure 6— *National Park Service map of Longmire Area Trails, available at Mount Rainier National Park facilities.*

Longmire Walk 1—Longmire Meadows and Trail of the Shadows

Logistics: 1 hour

At the crosswalk, proceed cautiously across the highway to the meadow on the north side. Walk 0.2 kilometer (0.1 mile) to a small side trail on the left where interpretive signs provide general information about Longmire warm springs, Rampart Ridge, and local history. From there, walk along The Trail of the Shadows, a 1.1 kilometer (0.7 mile) loop around Longmire warm mineral springs, through forest and wet meadow. Interpretive signs describe the hotel, homestead, and spa built by James Longmire. Stop at each interpretive sign to obtain information about the springs, history, flora, and fauna. As with all hikes made within the park, students should remain on the trail. Use the questions below to encourage discussion.

Features of Interest:

1. Rampart Ridge lava flow
2. Longmire warm springs

Background:

Rampart Ridge lava flow:

- ***For much of the period when volcanism was building the mountain, glaciers covered a large part of Mount Rainier National Park.***
  Now try this mental exercise. Imagine yourself standing here in parka, hat, and gloves between 370,000 and 380,000 years ago. At your present location, you would be buried by 400 meters (1,300 feet) of glacial ice from the ancient Nisqually River Glacier. This enormous glacier stretched for tens of kilometers (tens of miles) from Mount Rainier's summit towards the Puget Sound lowlands to the west.

- ***Lava flows were constrained by large glaciers.***
  During this period of large glaciers and volcanic eruptions in what is now Mount Rainier National Park, many lava flows poured down the mountain's southwestern slope. Large glaciers in the Nisqually River and Kautz Creek Valleys constrained the movement of each lava flow. Each successive lava flow ponded between the two glaciers where it cooled and hardened. Later, changing climatic conditions caused the glaciers to thin and recede. The thick stack of cooled and hardened lava flows remains as Rampart Ridge.

- ***What formed the columns?***
  The lava flow cooled and hardened from the outside inward. Lava adjacent to glacier ice cooled within hours; the interior of the flow cooled over years to decades. As lava cooled and solidified, it contracted and cracked into long columns with polygonal cross sections. The columns aligned in the direction of greatest cooling. Columns on the cliff face are vertical because most heat is lost through the upper surface. Smaller horizontal columns that pointed horizontally toward the glacier margin once covered the lava flow sides, but most have been stripped away by erosion.

- ***Longmire warm mineral springs:***
  Longmire springs obtain their heat from hot rock located several miles beneath Mount Rainier. Water flows downhill and percolates through the volcanic rock and through the still warm feeder systems that supplied lava to the surface. At the same time, hot gases rise from magma stored 8 to 10 kilometers (5 to 6 miles) below the Earth's surface. The resulting hot water then mixes with cool shallow groundwater. The present temperature of springs is about 28 degrees Celsius (83 degrees Farenheit). During the 1920s, the park employees recorded the presence of about 50 springs, although the current number is less.

- ***Gas bubbles at Longmire warm springs consist largely of carbon dioxide (CO_2).***
  Most of the carbon dioxide at Longmire is volcanic in origin. Bubbles form because more CO_2 is supplied from below than can dissolve in the water. Carbon dioxide is denser than air, and can temporarily accumulate in low spots along the ground where it displaces oxygen and regularly kills birds and short-legged animals that venture into the springs for warmth and water. Not enough CO_2 is released at Longmire to be harmful to humans.

Figure 7— *Reconstruction of an historical visitor facility at Longmire. USGS photo by C. Driedger.*

Discussion questions for first stop in the meadow:

Rampart Ridge lava flow dominates the northern horizon:

Observe the cliff face on the ridge. Encourage discussion with the following guiding questions:

- Ten thousand or more years ago, what feature filled this valley? ***The ancestral Nisqually River Glacier***.
- What natural feature flanked and bounded the lava as it flowed into place? ***Glacier ice.***
- Explain why the lava flow top is hundreds of meters above the valley floor. ***The glacier once filled this valley to an elevation roughly equivalent to the present ridge top. Lava that flowed beside the glacier cooled and hardened as Rampart Ridge. The glacier melted and Rampart Ridge remains***.
- What is the origin of the columns (or "colonnades") in the cliff face? ***Interior rock cooled, contracted and fractured into polygon-shaped columns. These columns pointed toward the nearest cooling surface. Columns on the cliff face of Rampart Ridge point upward. Erosion has stripped away the smaller horizontal columns that abutted the glacier margin.***

Soda Spring:

The Soda Spring and site of the former Travertine Mound are ideal spots to ask the following guiding questions:

- Why do warm springs exist here? ***Warm rock beneath the surface heats groundwater.***
- Look for evidence that the spring's temperature is warm and not hot. If you have a thermometer, measure the temperature. ***The lack of persistent steam and the presence of vegetation nearby is an indication that the spring water is warm but not hot. The water temperature is variable and is dependent on the amount of groundwater present.***
- What causes bubbles to rise? ***Carbon dioxide rises through groundwater.***
- Is the water smelly? ***No.*** Is the air smelly? ***Potential odor from decaying vegetation.***
- Is the water clear or cloudy? ***Generally clear.***
- Why do dead trees exist in the springs area? ***Trees have been drowned by rises in water level caused by mineral buildup and by beaver dams.***
- Why are there so many mineral deposits around the outlets to the hot springs? ***Minerals dissolved in groundwater precipitate when the water cools.***
- Name some other volcanic areas of the world where water is heated by volcanic rock. ***Yellowstone, Lassen Peak, Mount Baker, Mount Fuji, Iceland, and others.***

Longmire Walk 2—Rocks on Buildings and Bordering Paths

Logistics: 30 minutes

Spend 30 minutes or so exploring the terrain in the vicinity of buildings at Longmire, including the small museum and log slice out front. With small groups of students, walk the pathways between National Park Inn, the museum, and the Wilderness Information Center (WIC) in the administration building (rustic building with the flag pole out front). Obtain a current map of Longmire from the Longmire Museum.

Figure 8—*Administration building at Longmire constructed with local rocks. National Park Service photo.*

Features of Interest:

1. Rocks within the building foundations and path borders at Longmire administration building have fascinating stories to tell.
2. Longmire Museum and transportation exhibit at the historic gas station provide a comprehensive history of visitor use of the park.

Background:

- ***The slice of log outside of Longmire Museum displays a timeline of geologic and historical events.***
  This is an ideal spot to view some of the history of much of Western civilization as chronicled on a slice of log. The tree from which it came stood strong through eruptions, lahars, and human intrusion into the region. Encourage students to read its event labels.

- ***Rocks in path borders and building walls display rocks of local origin.***
  During the 1930s, construction crews collected rounded, smooth-surfaced boulders from the riverbed as construction material for the buildings and path borders. Two rock types are common in the foundations and path liners—the reddish-gray Mount Rainier andesite, which was erupted from the volcano, and the lighter colored salt-and-pepper Tatoosh granodiorite (a variety of granite). About 17 million years ago, magma (hot, molten rock) worked its way upwards through Earth's crust and cooled as granodiorite about 8 to 16

Figure 9—*Tatoosh granodiorite is labeled as shown. The gray and red rock are Mount Rainier andesite. USGS photo by C. Driedger.*

kilometers (5 to 10 miles) below Earth's surface. Movement of Earth's crust forced the entire region upward during formation of the Cascade Range around 10 million years ago. As the mountains rose, erosion stripped away the surface rocks and eventually exposed the harder Tatoosh granodiorite. The Tatoosh granodiorite is visible immediately south and southeast of Longmire as many of the peaks of the Tatoosh Range.

- ***Minerals in some rocks are conspicuous and others less so.***

  The common white crystals in the granodiorite are mostly feldspars with lesser amounts of quartz; the black crystals are hornblende (somewhat elongate) and biotite (shiny dark mica). Feldspar is also conspicuous in the volcanic boulders as scattered white-to-clear crystals, accompanied by lesser pyroxene (brown and green) and sometimes a little hornblende. The darker groundmass in which those crystals are set consists of the same mineral types but are too tiny to distinguish without the aid of a strong magnifying glass or microscope.

- ***Rock origins determine rock appearance.***

  This is an ideal place for students to compare the sizes of crystals in the granodiorite with those in the boulders of Mount Rainier lava. The chemical compositions of the granodiorite and the andesite lava are about the same, indicating that they solidified from similar types of magma. However, the crystals are different sizes because the granodiorite cooled slowly underground giving more time for its crystals to grow ("slowly" means 100,000 to 1 million years to solidify, depending on circumstances). Long times at lower temperatures also account for the presence of quartz, hornblende, and biotite in the granodiorite versus their scarcity in the volcanic rocks. The prominent crystals in the lava also grew underground, but their growth was arrested when the lava erupted and chilled. The dark, fine-grained groundmass was largely or wholly molten at the time of eruption, and rapid posteruptive cooling allowed it to grow only tiny crystals. Some of the lavas cooled quickly and did not have time to crystallize but instead solidified as glass.

Discussion questions for use at pathways and stone buildings:

- **Rocks at Longmire:**
  Many boulders line the paths between the parking area and the meadows and are visible in the walls of Longmire area buildings. What kinds of rocks are these? How did they form? Why are they rounded? ***Boulders are andesite and granodiorite. Andesite formed as Mount Rainier lava flows; granodiorite formed as a mass of rock (pluton) beneath the Earth's surface that cooled and hardened over hundreds of thousands to millions of years. Stream-flow action rounded the boulders.***
- Explain the evidence of this being volcanic terrain. ***Students are close to Mount Rainier and the Rampart Ridge lava flow; warm springs exist nearby; volcanic rocks are found in abundance.***
- Instruct students to examine the rocks and record observations as written notes or in drawings. How many different rock types can they classify? ***Generally, two types of rocks are visible here—andesite and granodiorite. Both are igneous rocks. Most of the andesite boulders came from Mount Rainier, but some students may recognize that there are also brownish andesites that form rock outcrops up the path (north into the woods) in front of the administration building and also at the bridge across the Nisqually River behind the Longmire employee compound. These are older andesites that erupted 30–40 million years ago and form the regional basement into which the Tatoosh granodiorite intruded.***
- Encourage students to make visual observations or use magnifying glasses. Students should note texture, crystal size, and color. Which rocks took longest to cool? ***Rocks with largest crystals—generally granodiorite here.*** Which took the shortest time to cool? ***Andesite—especially those with small crystals.***
- Which rocks cooled inside the Earth (were intrusive)? ***Granodiorite.*** Which rocks cooled on Earth's surface (extrusive)? ***Andesite.***

The small picnic area in front of the flagpole is a good place to conduct the **Magma Mash** activity from the Educator's Guide. This activity illustrates why crystals in some igneous rocks are large and others are small.

Longmire Walk 3—Bridge over the Nisqually River at Longmire

Logistics: 30 minutes

Walk 0.5 kilometer (0.3 mile) through the park residential area to the road bridge that crosses the Nisqually River. Note: If you intend to do the coffee filter experiment for analysis of glacial flour (see page 19), bring materials with you—a bucket, graduated cylinder, funnel, several coffee filters, and a small scale. (Or you may want to collect water now and do the experiment back at school.)

Figure 10— *Nisqually River from Longmire bridge. USGS photo by C. Driedger.*

Features of Interest:

River characteristics:
Rounded river rocks, clear or sediment-laden river water (season dependent), and scouring and aggradation of the riverbed caused by erosion and deposition of river rocks.

Background:

- ***Glaciers ground rock to make glacial flour.***
  The Nisqually River originates 8 kilometers (5 miles) up the valley as melt water from the Nisqually Glacier. The glacier grinds rock against rock and produces an abundance of fine-grained sediment (glacial flour) that is transported by river water (glacial milk). The amount of glacial flour is greatest in summer and, at times, absent during winter. Along the way, glacial waters are diluted by water of nonglacial origin from tributary streams such as Van Trump Creek and the Paradise River. The rocks supporting the ends of the bridge, and visible just upstream along the river, are andesites of the Ohanapecosh Formation that erupted 30 to 40 million years ago from multiple volcanoes much older than Mount Rainier.

- ***The riverbed is routinely modified by natural processes.***
  Floods of 2006 carried boulders to this area, locally filled the channel, and allowed river water to erode the river embankments at Longmire. Park staff later plowed a wide channel

Experiment—Coffee filter analysis of glacial flour—how much glacial flour is in this glacial stream?

Try this experiment with your students at home or during your trip. Determine the amount of glacial flour in a glacial runoff stream by obtaining 10 liters (~2.6 gallons) of river water (obtainable with care at the base of the bridge). Using a standard 1 liter (33.8 fluid ounce) water bottle will require 10 dips and dumps. Weigh a coffee filter on a small scale and then place it in a funnel. Pour the water through the filter so that the glacial flour sticks to the filter. Let the coffee filter dry in the sun. Weigh the whole sample and subtract the original weight of the filter. During summer, you should find that as much as 500 grams (18 ounces) have settled out of 10 liters of water. Try the same experiment with water from different streams, glacial and nonglacial, and in different seasons.

From: Glaciers of North America Field Guide by Sue Ferguson, 1992, Fulcrum Publishing, Golden, Colorado, 176 pages.

Discussion questions for Nisqually River bridge:

Water cycle:

- Encourage students to trace the water cycle of which this river water is a part. ***The water originates as moisture in marine air masses over the Pacific Ocean. As winds blow in from the Pacific, air is forced upward by Mount Rainier, cools, and the moisture within drops as rain or snow. Groundwater and water in the river might have come from rain, melted snow, or melted glacier ice.***
- What processes in the water cycle are taking place during your visit? ***Possibly rain or snowfall, and (or) snowmelt, evaporation, cloud building, and water flowing off the mountain towards the ocean.***
- Explain how the Nisqually River here differs in appearance from rivers in the lowlands near your community. ***It contains a lot of large boulders, and it has seasonal fluctuations in velocity, width and depth, and sediment content.***
- What is the source of this water? ***Nisqually Glacier is the principal water source.***
- Explain how the stream flow fluctuates throughout the year. ***Stream flow is higher in summer and early fall, when snow and ice melt are most intense.***

Rocks in the Nisqually River:

- What type of rocks are found here? ***Mount Rainer volcano (andesite) and rocks from the Tatoosh Range (generally granodiorite).***
- Explain the origin of the downed trees in the riverbed. ***The river embankment was undercut by river water, and the trees fell onto the riverbed.***
- Are the rocks angular or rounded? Why so? ***Rounded because the sharp edges were ground off by collisions with other rocks in the river channel and polished by river flow.***
- Explain the origin of rocks in the riverbed. ***Rocks were eroded upstream and transported here by water and accumulate in the riverbed by a process called deposition or aggradation.***

Flooding:

- Identify evidence of flooding in the Longmire area. ***There are many boulders on the surface adjacent to the riverbed.***
- Explain what actions people have taken to reduce the likelihood of flooding at Longmire. ***People constructed dikes, plowed a deeper channel for the river, and built the bridge high above the river.***
- Explain how changes in river flow can affect human, animal, and plant life. ***Reduction in the amount of stream flow can deprive life forms of water; excess water can flood ecosystems. Flooding can damage or destroy community infrastructure.***
- As changes in climate hasten loss of snow and ice, how will the volume of river water change? ***Water flow could increase in the short term. When the glaciers and snowpack are greatly reduced, the amount of water in the river could decrease. Precipitation that falls as rain instead of snow will be stored as groundwater or flow away in a few days, rather than stored over the course of an entire season or longer.***

Christine Falls and the Tatoosh Pluton Granodiorite Mile 10.8

Logistics: Slow Pass

Safety note: Please do not stop the bus on the bridge over Van Trump Creek, but have the driver slow down and put on emergency flashers. Students get a safe view of upper Christine Falls during a "slow pass" across the highway bridge.

Figure 11— *Granodiorite of the Tatoosh Pluton near Christine Falls (keychain for scale). USGS photo by C. Driedger.*

Features of Interest:

1. Granodiorite rock from Tatoosh Pluton
2. Upper Christine Falls

Background:

- ***Tatoosh granodiorite:***
  This is one place where the 17 million year old Tatoosh granodiorite is visible at the surface. Viewing it along the roadside can be hazardous, so get an armchair view of it through the bus window.

- ***Christine Falls is good example of a hanging-valley waterfall:***
  Van Trump Creek falls off the Rampart Ridge lava flow into the Nisqually River Valley. View Upper Christine Falls in a narrow glen on the north side of the highway bridge (left side as proceeding from Longmire to Paradise). The bridge conveys you directly above Christine Falls. Observe it from a viewpoint adjacent to the parking lot.

- ***Debris Flows in Van Trump Creek:***
  On numerous occasions in recent years, stream water picked up and transported loose rock as debris flows, which swept down the valley of Van Trump Creek.

Glacier Bridge

Mile 11.6

Logistics:

Safety note: Please do not stop the bus on Glacier Bridge, but have the driver slow down and put on emergency flashers. Students get a safe view of the Nisqually River during a "slow pass" along the highway bridge.

Figure 12— Nisqually River valley as seen from Glacier Bridge. USGS photo by C. Driedger.

Features of Interest:

1. Nisqually River and Glacier
2. Evidence of glacier retreat

Background:

- ***Valley of the Nisqually River:***
  The Nisqually River originates at the terminus (lower end) of Nisqually Glacier, marginally visible 1.9 kilometers (1.2 miles) upvalley. Nisqually River is a "braided stream." For information about braided streams, see page 24.

- ***Road up the side of Ricksecker Point lava flow:***
  On the east side of the bridge, the road turns to the south and clings to the cliff of the Ricksecker Point lava flow.

- ***Imagine yourself face-to-face with Nisqually Glacier.***
  In 1840, the terminus of the Nisqually Glacier lay just downstream of the present bridge. Now imagine it was in the 1880s, and you are accompanying early entrepreneur James Longmire on a hike up the riverbed to obtain glacier ice for his hotel's ice house. Longmire complains that he is forced to travel farther each year as the glacier terminus retreats up valley. Longmire's complaint became one of the first written records to document Nisqually Glacier's recession.

  Over the next 120 years, the glacier thinned and receded beyond the curve in the valley wall. Since that time, the glacier terminus has made small advances and recessions but never regained its former position in the vicinity of the Glacier Bridge. Read more about Nisqually Glacier in the descriptions for the next stop and in the background notes for Paradise.

Figure 13— Nisqually Glacier terminus at river crossing in 1908. Photo by A. Curtis, Courtesy of Washington State History Museum.

Ricksecker Point Loop Road—North

Mile 12.7

Logistics: 15 minutes

Turn right on the Ricksecker Point Loop Road and park into the first lot on the right.

Features of Interest:

1. View of Mount Rainier's inner structure
2. Ricksecker Point lava flows
3. Nisqually Glacier and River
4. Evidence of rock and water cycles

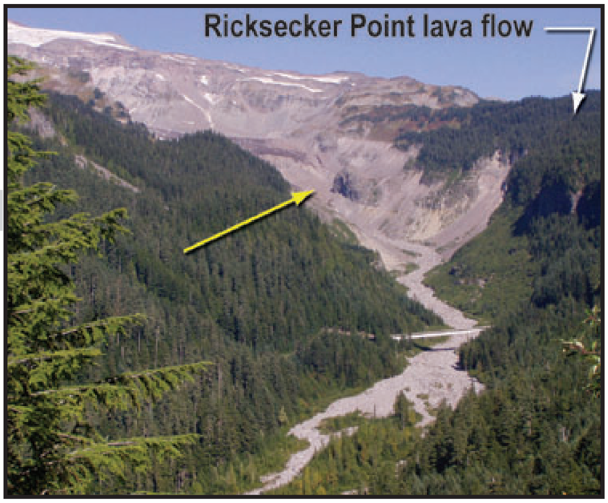


Figure 14— *Nisqually Valley from Ricksecker Point North. White arrow indicates location of Ricksecker Point lava flow, and yellow arrow indicates terminus of Nisqually Glacier. USGS photo by C. Driedger.*

Figure 15— *Loose rock rubble from top of the 40,000-year-old Ricksecker Point lava flow. USGS photo by C. Driedger.*

Background:

- ***Ricksecker Point lava flow:***
  Chances are that you are familiar with red hot lava flows from seeing them on TV shows. But now, here you are standing on top of lava flows that cooled and hardened. The Ricksecker Point lava flow on which you stand flowed into place about 40,000 years ago. This lava flow towers above the Nisqually River, as does the high-perched Rampart Ridge lava flow (380,000 years old) lava flow across the valley. It is a good place to contemplate why the lava flows exist so high above the present valley floor. As you drive towards the parking lot at Ricksecker Point South, be aware of the rubbly lava rocks that might have toppled onto the road surface.
- ***View of Mount Rainier's inner structure:***
  In clear weather, this stunning vista presents opportunities for discussion about Mount Rainier's inner structure. Glaciers and rock fall have stripped away overlying rocks to expose hundreds of lava layers, each 15 meters (50 feet) thick or more. The steep cliff bands are the dense flow interiors, whereas the intervening rubble slopes are the rubbly flow tops. The layering of hard lava and loose rocks creates a cliff-and-slope appearance, and preservation of the rubbly flow tops shows that the successive lava flows erupted in rapid succession. Such bursts of volcanic activity, separated by longer periods of few eruptions,

typify Mount Rainier's history, as well as that of the other active Cascade volcanoes. Some of the rubble slopes are deposits of pyroclastic flows (fast avalanches of hot lava fragments), but these cannot be distinguished from the more abundant rubbly tops of lava flows at this distance.

- ***Viewing Nisqually Glacier:***
  Ricksecker Point North is a grand place to observe Nisqually Glacier and evidence of its advances and retreats. The glacier's maximum position during the Little Ice Age (a period of global cooling from A.D. 1300 to 1850) was about 0.2 kilometer (0.1 mile) downstream of Glacier Bridge. About 2 kilometers (1.2 miles) of recession has occurred since the mid-nineteenth century. Moraines of the later part of the Little Ice Age hang on the valley walls and are a source of frequent rock fall. The interpretive sign illustrates the location of the glacier terminus through time. Nisqually Glacier is confined within steep valley walls, and through the course of glacier motion over many millennia, erosion by ice-bound rocks has deepened and widened the valley into the U-shape characteristic of glacier valleys. Learn more about Nisqually Glacier in the Nisqually Vista Trail section of this guide.

- ***Nisqually River—A braided stream:***
  During the summer months, rivers are swollen with snow and ice meltwater and heavily laden with boulders, gravel, and glacial flour, the fine-grained rock milled at the glacier bed. When the river level subsides, the boulders and gravel are deposited to form channels and bars. The water flows in a braided pattern around the islands and bars. The view from Ricksecker Point North shows several braids on the valley floor.

- ***Evidence of the rock and water cycles:***
  From this spectacular vantage point, several stages of the rock cycle are in evidence—some rocks that are intact within Mount Rainier, rock fall onto the glacier surface, rocks in the riverbed, and fine-grained sediment carried in river water. These are evidence of mountain building, weathering, and erosion. Phases of the water cycle are seen as clouds, precipitation, snow and ice, river water, moist forest soils, and vegetation.

Discussion questions for Ricksecker Point North Viewpoint:

Nisqually Glacier:

- ◆ Ask students to point out the summit of Mount Rainier and the head of Nisqually Glacier on its southern flank. Ask them to look for evidence that Nisqually Glacier was formerly present downvalley of its current location. ***U-shaped valley and erosionally smoothed surfaces on rocks.***

River width:

- ◆ Explain why the riverbed is so wide and with so little water flowing across it. ***The volume of stream flow is changeable and depends on precipitation and snowmelt and the presence of glacier outburst floods. In addition, the heavy load of rocks deposited on the valley floor over the years has caused the river to shift position.***

Water cycle:

- From this viewpoint, view water in a variety of forms. Identify the various stages of the water cycle that are visible from here. ***Water exists in the clouds, glaciers, snow, river, and in the moist forest soils.***

Rock cycle:

- From this viewpoint, students can observe rocks in a variety of phases in the rock cycle. Ask students to identify the various stages of the rock cycle that are in view from here. ***Several stages of the rock cycle are in evidence—rocks intact within the face of Mount Rainier, rock fall on the glacier surface, rocks in the riverbed, and fine-grained sediment carried in river water.*** Ask students where the river will carry and deposit the fine-grained material that it carries downstream. ***Some of the fine-grained rock will be deposited in Alder Reservoir and ulimately in the Pacific Ocean. Pieces of these rocks might become part of sedimentary rocks; these rocks might be metamorphosed, or melt and form magma to be erupted again.***

Rocks in the manmade walls of the parking lot:

- What color are the rocks in the manmade walls of the parking lot? ***Salt-and-pepper.*** Are they alike or different from rocks in the valley wall? ***Rocks in the valley walls are darker in color because they consist of lava erupted from Mount Rainier. The salt-and-pepper granodiorite was eroded from cliffs of the Tatoosh Pluton located upstream from Glacier Bridge (and under the lava flows).***

Ricksecker Point Loop Road—South

Logistics: 15 minutes

Note: Ricksecker Point loop road is closed in winter.
Drive approximately 0.6 kilometer (0.4 mile) to the Ricksecker Point parking lot located at the switchback in the road. This viewpoint is located at the tip of the lava flow.

Figure 16— *Mount Rainier from Ricksecker Point South. USGS photo by C. Driedger.*

Features of Interest:

1. Panoramic view of Mount Rainier
2. Interactions between lava flows and glaciers
3. Top and toe of Ricksecker Point lava flow
4. Tatoosh Range (pluton of pre-Mount Rainier rocks)
5. Paradise Lahar

Background:

- ***The toe of this lava flow was constrained at the juncture of two massive ice-age glaciers.***
  Ricksecker Point lava erupted during a period of extensive glaciation. The present overlook is close to the level of the glaciers' surface, during the Ice Age, when one could have walked across the ice to Rampart Ridge above the chasm now occupied by the Nisqually River or across to Eagle Peak and the Tatoosh Range above the present Paradise River valley. During repeated eruptions, lava streamed down the south side of Mount Rainier and flowed along the margin of the approximately 240 meter (800 foot) thick ancestral Nisqually River Glacier to the west and the ancestral Paradise River Glacier to the east. Lava probably advanced along the crest of an ice-buried ridge between the flanking major ice streams because the ice was thinnest along that route. At the confluence of the two glaciers near the present location of Ricksecker Point, much or perhaps all of the lava pooled, cooled, and hardened. After the glaciers retreated, the Ricksecker Point lava flow remained stranded high above the surrounding terrain. The down-valley toe of the lava flow supports the present roadway at Ricksecker Point. See the activity Fire and Ice in the Educator's Guide for more information about how this phenomenon was important in the shaping of Mount Rainier.

- ***Rubbly top of Ricksecker Point lava flow.***

  This feature is visible in the toe of the lava flow—the outcrop northeast of the parking lot. Andesite lava flows typically consist of a dense interior with elongate columns in which pasty lava cooled slowly, shrank, and cracked, overlain by a carapace of loose rubble. This rubbly flow top forms because the upper surface of the lava flow cools quickly and hardens as the flow continues to move. The rocks of the flow top are jostled and broken and grind against one another forming a rubbly carapace. Note the lava "squeeze-ups" (ridges and spines of solid rock) where molten lava from the hot interior of the flow intruded into the rubbly top of the flow. These rubbly flow tops erode quickly and are preserved only if the flow is relatively young or early on is buried by succeeding lava flows. The Ricksecker Point lava flow is about 40,000 years in age—one of the younger of the large ridge-producing flows in Mount Rainier National Park (the youngest known lava flows from Mount Rainier erupted about 2,800 years ago, are exposed along the rim of the summit crater and underlie the Emmons and Winthrop Glaciers on the opposite side of the volcano). The flow top rubble is quite unstable and produces frequent rock fall onto the roadway.

- ***Other rocks identifiable from Ricksecker Point South.***

  This location offers a view of pre-Mount Rainier rocks (Tatoosh granodiorite) in the Tatoosh Range to the south and in the roadway guard walls constructed around the periphery of the parking lot.

Discussion questions for Ricksecker Point South Viewpoint:

Origin of the valley:

- Develop a hypothesis about the origin of the valley. ***Glacial ice flowed down the valleys of Paradise Creek and the Nisqually River and joined here. Lava flowed from Mount Rainier and was confined between the confluence of these two glaciers. The lava cooled and hardened. When the glacier melted, the lava flow was stranded high above the valley floor.***
- Near this point, elevation of the Nisqually River Valley floor is approximately 1,040 meters (3,400 feet). You are standing at elevation 1,280 meters (4,200 feet). Calculate a minimum ice thickness when the lava flow formed (erosion rates in hard granodiorite are slow, so the valley floor was almost exactly the same elevation 40,000 years ago). ***Answer is approximately 240 meters (800 feet).***

Volcanic processes:

- While viewing Mount Rainier, name the processes that formed the multiple layers (seen in profile) on the volcano. ***Lava formed the solid rock layers; pyroclastic flows and loose rock from lava flow tops formed the intervening loose rock layers.***
- List the geologic processes that formed the landscape. ***Volcanism, glaciation, and erosion by water flow.***
- List some evidence for repeated volcanism at Mount Rainier National Park. ***Hundreds of lava flows erupted through time built the ridges that radiate from Mount Rainier.***
- Explain how volcanic activity at Mount Rainier differs from activity at other types of volcanoes, such as Hawaiian volcanoes. ***Lava here is more viscous than at Hawaiian volcanoes and capable of accumulating as a steep-sided pile—that is, as a stratovolcano.***

Paradise Visitor Facilities

Mile 17.6

Logistics: 30 minutes to 5 hours

Note: Obtain the most recent map of trails at the visitor center. Consider one or more options:

Option 1—View the Paradise Jackson Visitor Center exhibits and theater (30 to 60 minutes+). Note: Cafeteria and gift shop also are located in the visitor center.

Option 2—Hike the Nisqually Vista trail 1.9 kilometers (1.2 miles) roundtrip (1.5 hour). ***Note: Group snowshoe walks are available by prior arrangement in winter.***

Figure 17—*The Paradise Jackson Visitor Center. USGS photo by C. Driedger.*

Option 3—Make longer hikes to Alta Vista 2.8 kilometers (1.75 miles) round trip, Glacier Vista (3.2 kilometers or 2.0 miles round trip), and Panorama Point (6.4 kilometers or 4.0 miles round trip). Allow about 5 hours for the Panorama Point trip. A 1.2 kilometers (1 mile) short hike leads to Myrtle Falls. Trails begin just outside the north doors of the visitor center. ***Note: Option 3 trails are snowbound in winter and travel there is not appropriate for school groups.***

Note: If you intend to conduct the bug string experiment (page 35), choose hike options 2 or 3. If you intend to do the glacial striations experiment (page 43), choose option 3. Consult those sections for a list of equipment required.

Features of Interest:

1. Alpine meadows and views of other volcanic features and landforms (Mounts Rainier, Adams and St. Helens, and the Goat Rocks, the Tatoosh Range, and basalt flows to the east)
2. Visitor Center, location on the Ricksecker Point lava flow
3. Tephra layers (material ejected from a volcano that falls to the ground; when less than 2 millimeters (0.08 inch), it is called volcanic ash)
4. Paradise Lahar
5. Glaciation

Figure 18— *Boulders from the 5,600-year-old Paradise Lahar protrude at the surface over much of Paradise Ridge. Sandy layers of volcanic ash from eruptions of Mount Rainier and Mount St. Helens overlie and underlie boulders of the Paradise Lahar. USGS photo by C. Driedger.*

Paradise Area Trails—Mount Rainier National Park

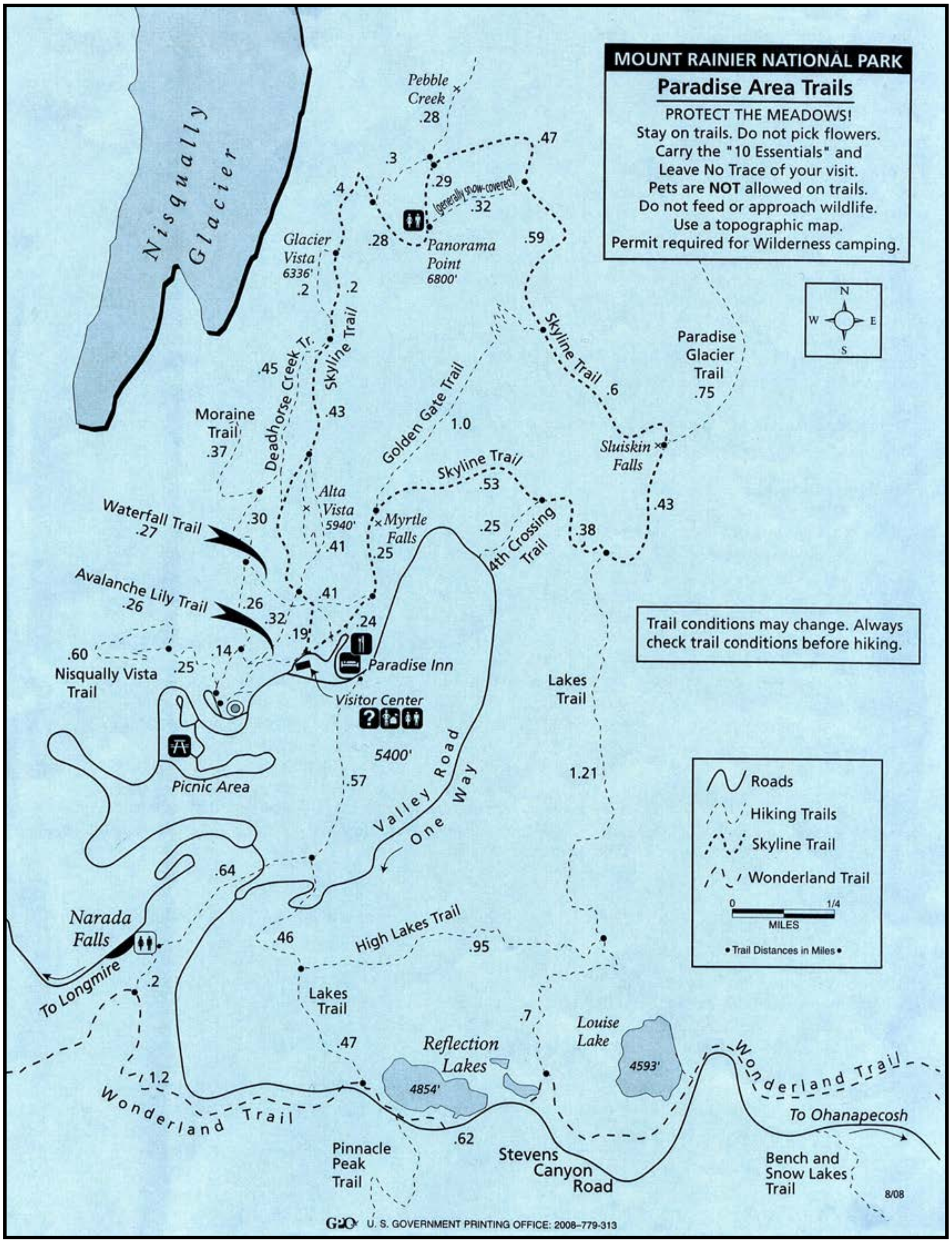


Figure 19*— National Park Service map of Paradise Area Trails, available at Mount Rainier National Park facilities.*

Background:

Figure 20— *Layer Yn erupted from Mount St. Helens in A.D. 1479 and found near the surface around the south side of Mount Rainier. Lens cap shown for scale. USGS photo by C. Driedger.*

- ***The Paradise visitor facilities are built on a thick stack of lava flows that are overlain by lahar deposits and tephra layers.***

  In the vicinity of the Paradise visitor facilities, the 40,000-year-old Ricksecker Point lava flow (which sits on a stack of older lava flows) is covered with an undulating surface of rock debris left there by several lahars, most notably the 5,600-year-old Paradise Lahar and the 7,200-to 7,400-year-old Reflection Lakes Lahar. The Paradise Lahar formed by collapse of rock near the summit of Mount Rainier. It swept down the southeast side at about the same time that the Osceola Mudflow swept down the mountain's northeast side. Most of the Paradise Lahar descended the valley of the Nisqually Glacier and River, but rocky deposits on valley walls show that the Paradise Lahar also swept over Paradise and Mazama Ridges and filled the valley between Ricksecker Point and the Tatoosh Range—a thickness that temporarily may have exceeded 250 meters (820 feet). When the more liquid part of the lahars drained away, they left behind large boulders on the surface. These boulders are easily identifiable along the trails around Paradise as isolated blocks and by their light brown and yellowish brown colors that result from hydrothermal alteration by hot gases near the volcano's summit. The Reflection Lakes Lahar was one of many collapses that have occurred on Mount Rainier. The undulating surface left behind by these and other lahars are responsible for the numerous small hills and ponds, such as Reflection Lakes southeast of Paradise.

- ***Tephra layers at Paradise:***

  The sandy layers evident in many road and trail embankments are layers of tephra. Wind blew volcanic ash and larger pieces of pumice here from eruptions at Mount Rainier, Mount St. Helens, and ancient Mount Mazama (present-day Crater Lake, Oregon). Material from tephra eruptions of Mount Rainier are poorly represented at Paradise because most of the volcano's ash was blown to the eastern flank. The tephra layers have been distorted or removed entirely in most outcrops by the action of burrowing animals, plant roots, surface water movement, and long-term slope creep. These actions leave us with an imperfect and minimal record of eruptions.

Common Tephras found in the vicinity of Paradise:

LAYER Wn	LAYER Yn	LAYER D	LAYER O
Mount St. Helens	Mount St. Helens	Mount Rainier	Mount Mazama
A.D. 1479	about 3,700 years ago	about 7,000 years ago	about 7,700 years ago
• white to gray and brown • sand-size ash	• yellow to brown • coarse particles	• yellowish - to reddish brown • coarse pumice and scoria	• yellow-orange to pale-brown • silt-size ash

- ***Ice ages:***

  The past 2 million years of Earth's history were typified by the development of extensive glaciers in high mountains and also covering large areas of northern North America, Europe and Asia, alternating with nonglacial times. This time is known as the Pleistocene or in popular literature as the Ice Age. Worldwide, ice advanced and retreated. Over the 500,000 year existence of Mount Rainier, periods of widespread glaciers have each lasted from 90,000 to 120,000 years, separated by intervals of thousands to a few tens of thousands of years when climate was more like that of today. Smaller fluctuations in ice extent were superimposed on these major advances and retreats. The last period of extensive glaciation ended about 11,000 years ago. Between the fourteenth century and A.D. 1850, many of the glaciers on Mount Rainier advanced to their farthest extent downvalley since the last ice age. This period when glacier advances occurred worldwide became known as the Little Ice Age.

- ***Nisqually Glacier history:***

  On at least two occasions (about 150,000 years ago and then again about 20,000 years ago) Nisqually Glacier extended as far as approximately 60 kilometers (37 miles) from Mount Rainier to the site of Alder Lake Dam, west of the town of Elbe. During the past period of regional glaciation that peaked about 22,000 years ago, ice from the ancestral Nisqually River Glacier extended as far as the community of Ashford, approximately 32 kilometers (20 miles) from the foot of the mountain. During the Little Ice Age, Nisqually Glacier terminated 240 meters (800 feet) downvalley from the present site of Glacier Bridge (Highway 706) over the Nisqually River. After 1850, retreat of the Nisqually Glacier was slow until about 1920 when it hastened. Between the peak of the Little Ice Age and 1950, Nisqually Glacier and other large valley glaciers on Mount Rainier retreated about 1.6 kilometers (1 mile) up valley. Beginning in 1950 and continuing through the early 1980s, however, Nisqually Glacier and many other major glaciers advanced slightly in response to several years of relatively cooler temperatures. Since the early 1980s, Nisqually Glacier and most other glaciers on the mountain have been thinning and retreating. At the time of this writing (2014), the active terminus of Nisqually Glacier is located near the 1951 terminus position. As climate continues to change, at times making conditions less favorable for glacier growth, it is unlikely that Nisqually Glacier will disappear completely, but it will thin and become a much smaller glacier, residing higher on the slopes of Mount Rainier.

Logistics: 30 to 60 minutes+

Open daily in summer and on selected days during winter. Call or check the Mount Rainier National Park Web site for specific information. The parking lot fills by midday during summer weekends, less quickly at other times. In the visitor center, visit the Mount Rainier movie in the theater, and the large relief map on the first floor, and the exhibit area on the second floor. A gift shop and cafeteria are located in the same building. ***Obtain a current map of trails at the visitor center.***

Option ❶ Paradise Jackson Visitor Center

Figure 21— *Interactive displays about natural and human history are located on the second floor of the Jackson Visitor Center at Paradise. USGS photo by C. Driedger.*

Discussion questions for Geology Exhibits:

After viewing the exhibits, students should be able to answer these basic questions about the area.

- What are the other volcanoes of the Cascade Range between northern Washington and northern California? ***Mount Baker, Glacier Peak, Mount Adams, Mount St. Helens, Mount Hood, Three Sisters, Newberry Volcano, Mount Jefferson, Crater Lake, Medicine Lake volcano, Mount Shasta, and Lassen Peak.***
- Explain how precipitation is important to glaciers, rivers, and living things at Mount Rainier National Park. ***Fresh snow and rainfall feed glaciers and rivers and provide abundant moisture for plants and animals.***
- What is a glacier, and how does a glacier form? ***A glacier is a mass of ice formed from snow falling and accumulating over the years and moving in response to gravity.***
- Name some geologic processes that have shaped the area. ***Lava flows, volcanic ash fall, pyroclastic flows, lahars, glaciers, and rivers.***
- Name the principal hazards to people and structures on valley floors surrounding Mount Rainier. ***Lahars and debris flows.***

Logistics: 1.5 hours

Consider walking the 1.9 kilometer (1.2 mile) paved Nisqually Vista Loop Trail, which can be reached at the north side of the westernmost parking lot. Numerous paths lead to this trailhead, so seek advice from staff about the easiest way to reach it. This walk can be done in athletic shoes in summer through early fall; in hiking boots on compacted snow (June through mid-July); or with snowshoes (November through May). The National Park Service requires that hikers remain on the trails at all times, and if the trail is snow covered, that they follow trail flags carefully. Check hiking conditions before your trip. Hiking at high elevation can be tiring. Early summer hiking on this trail may be slippery and hazardous.

Option ② Nisqually Vista Hike

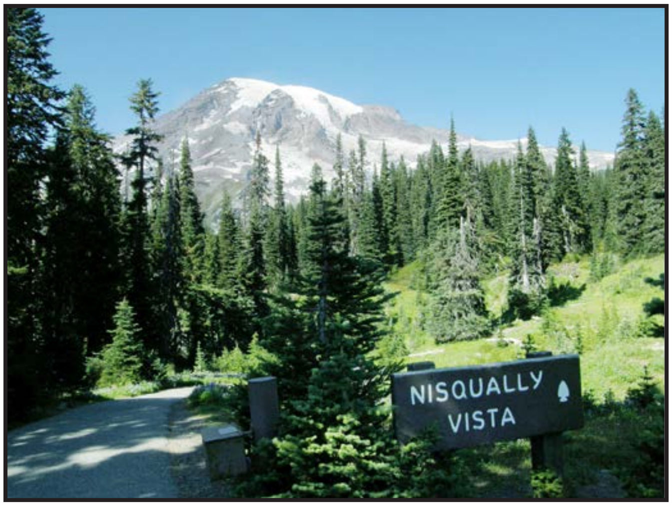


Figure 22— *The Nisqually Vista Loop Trail, paved and well marked, is suitable for hiking during summer and fall and for snowshoe walks during winter and spring. USGS photo by C. Driedger.*

Note to Teachers:

Before making this hike, read the materials carefully and plan to ask the discussion questions at each stop described. For the bug-string measurement (see page 35), you will need at least 1 hour between setting up and returning to the stakes.

Features of Interest:

1. Mount Rainier
2. Nisqually Glacier
3. Glacial moraines
4. Cross-section of the volcano
5. U-shaped glacial valley
6. Boulders left behind by lahars
7. Volcanic ash

Teacher background and guiding questions:

- ***Tephra layers:***
  Trail embankments are ideal locations to view volcanic ash as it erodes and falls into the path. Rock fragments called

Figure 23— *Tephra, reworked by water and by the actions of plants and animals is visible along many trails around Paradise. USGS photo by C. Driedger.*

tephra erupted from a volcano; pieces of tephra less than 2 millimeters diameter are called volcanic ash. Geologists designated the yellow-colored ash as layer Yn. It was erupted from Mount St. Helens about 3,700 years ago. In some places along this trail, find layer Wn (Mount St. Helens in A.D. 1479), and layer O (Mount Mazama, 7,700 years ago). See in-depth descriptions of these tephras on page 31. Reworking of the ash by water and by plants and animals has disturbed and mixed the layers and in many places made them indistinguishable.

Discussion questions for along trail where tephra is visible:

◆ What are the layers of sandy unconsolidated material? ***Tephra.***

◆ Where did these layers come from? ***Eruptions at Mount St. Helens, ancient Mount Mazama (present-day Crater Lake, Oregon). Most tephra from eruptions at Mount Rainier fell on the eastern flanks of the volcano.***

◆ In what ways is tephra important to plants and animals? ***The soft texture of tephra allows easy penetration by plant roots and burrowing by animals.***

- ***Weather station:***
  This pole-mounted station is a great place to talk about Mount Rainier's weather. The station contains instruments for measurement of air temperature, solar radiation, wind direction and speed, humidity, and precipitation, including a device that measures the depth of snow on the ground throughout winter. The record for snowfall at Mount Rainier was 8 meters (93 feet) set in the winter of 1971–72.

Figure 24—*The Paradise weather station, perched high above winter snowpack, is the source of weather data used by visitors and researchers. USGS photo by C. Driedger.*

Discussion questions for weather station area:

◆ Ask about the importance of this weather station to people. ***Information on snowfall helps us to quantify yearly water supplies for hydropower, drinking, and irrigation. The long-term weather record is used to identify climate changes. Current conditions reported from this station can help visitors make suitable plans for their visit to Mount Rainier.***

◆ Do you have the same weather station components at your school or community weather station? Why or why not? ***Answers will vary.***

◆ Challenge students to do a Web search when they return to the classroom and to find the current weather conditions at Paradise. ***Hint: Current conditions from this site are posted at the Northwest Weather and Avalanche Center.***

Journey Back in Time-continued . . .

Experiment—Bug-string measurements of snow melt rate. How fast is the snow melting?

1. For the bug-string measurement of snowmelt, you will need to allow at least one hour after setting up the stakes to see measurable snowmelt in the repeat measurement (more on hot and sunny days; on some days no melt will occur).
2. Beside the trail, on untouched snow, pound two wooden garden stakes securely into snow about 2 meters (6 feet) apart, taking care not to disturb the snow surface between them.
3. Connect the stakes with a string, 1 stretch the string taut, and then tie string to wooden garden stakes at height of approximately 8 centimeters (3 inches) above the snow surface.
4. Use a permanent marker to mark “bugs” (tick marks) approximately every 15 centimeters (6 inches) along the string.
5. Use a ruler to measure the vertical distance between snow surface and each bug on the string.
6. Record your measurements.
7. Return 1 hour or more later to repeat the measurements of the distances between the bug string and now surface.
8. Take an average of the original and repeat measurements, subtract values, and calculate melt rate per hour.

- ***Gas bubble boulder and other boulders left stranded by lahars of centuries ago:*** As you descend the hill towards the edge of the ridge, the trail passes one particularly large boulder that contains an enormous gas bubble. Expanding gases inflated the magma, which later cooled and hardened. Most of the large rocks on the surface were transported here by lahars that swept over the ridge. This is a good place to talk about the rock cycle and the processes that formed the rock and transported it. Look for other boulders along the trailside. The undulating ground surface is another legacy of lahars.

Figure 25— *Rock along the side of the Nisqually Vista Loop Trail, probably transported here by the 5,600-year-old Paradise Lahar, contains a large gas bubble. USGS photo by C. Driedger.*

Trail junction.

Take the trail on the right. In winter, the trail is snow covered; follow the flags carefully.

- ***Flower fields, twisted trees, and tadpoles:*** In summer, wildflowers fill the meadow with color. They sink their roots into the soft tephra from eruptions at Mounts Rainier and St. Helens. Tadpoles swim in small ponds during late summer and fall. The trail descends through trees. Note that heavy snow has bent and distorted the tops of many trees. If you are here in summer, observe that these trees, which have spent more than half the year surviving under snow, are badly misshapen.

Figure 26— *Flowering meadows are dependable attractions along the Nisqually Vista Loop Trail in summer, even during poor weather conditions. USGS photo by C. Driedger.*

- ***Nisqually Glacier viewpoints:*** Nisqually Glacier is evident from four viewpoints along the trail. The last viewpoint provides the best view and can accommodate an average-size class safely. An interpretive sign describes the glacier and its parts. ***Visitors should not climb on or beyond the rock retaining wall.*** The viewpoints are ideal locations to rest and discuss concepts and features noted in the bullets below.

Figure 27— *The terminus, or snout, of Nisqually Glacier is visible as a gray diamond-shaped feature in the lower center of the photograph. Rocks cover much of the lower glacier and make the glacier difficult to discern to the untrained eye. Red line indicates postion of glacier terminus. USGS photo by C. Driedger.*

- ***Nisqually Glacier is one of the most easily accessible and most studied glaciers on Mount Rainier.*** The glacier begins at the south edge of the summit crater and flows as much as 1 meter (3 feet) per day down a series of ice falls and then slows in the region 2.6 kilometers (1.6 mile) upvalley from the terminus, where it is joined from the west by the Wilson Glacier (left looking uphill). Nisqually Glacier is the fourth largest glacier by area on Mount Rainier. Scientists used radar devices to measure the ice and found it to be at its thickest about 1 kilometer (0.6 mile) up valley from the terminus—about 120 meters (400 feet) deep. Height of the terminus is approximately 30 meters (100 feet).

- ***Moraines and trimlines:*** Moraines are the sharp-crested ridges of unconsolidated rocks visible along the glacier's margins. Rocks fall off of cliffs onto glaciers, are transported, and then deposited along the glacier margins. Moraines can grow large when the glacier position remains stable over a period of years and are good indicators of a glacier's former dimensions. At Nisqually Glacier, the highest lateral (side) moraines record elevation of the ice during the 1840 advance (arrow on figure 28). Some of the roughly linear rock patches visible below the 1840 moraine are part of moraines formed during later ice advances in the latter part of the 19th century and during a brief advance in 1900. Look for trimlines, the distinct boundaries between older forest and younger pioneering vegetation that are visible above moraines on the glacier's west margin. Geologists determined the former extent of Nisqually Glacier and other glaciers by mapping the outline of glacial moraines and noting the position and ages of trimlines.

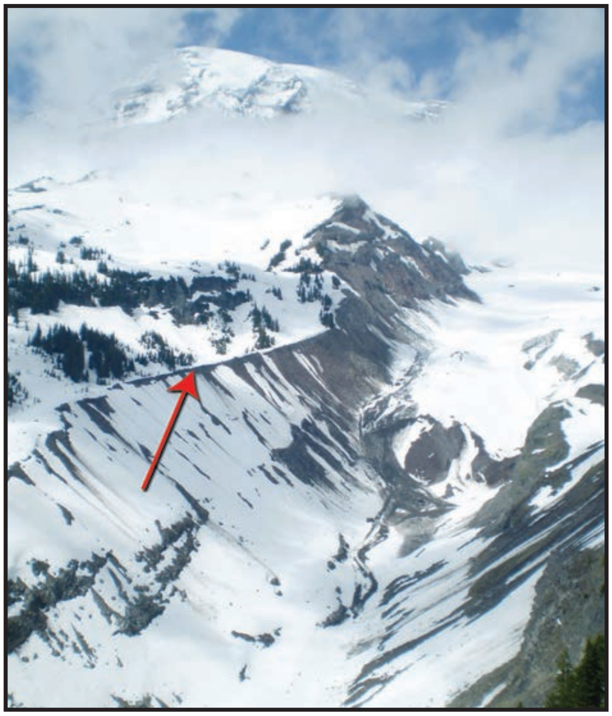


Figure 28— *Moraines from glacial advances in the nineteenth century are visible from the Nisqually Vista Loop Trail as sharp lines on the west valley wall at upper right of this photograph (red arrow) and in figure 27. USGS photo by C. Driedger.*

- ***Crevasses:***
  Glaciers flow faster near their surface and at centerline and slower near their bed and margins. The unequal flow rate causes the ice to tear and form crevasses. The ice also cracks as it rides over the crests of bulges in its rock bed. Most crevasses on Nisqually Glacier do not exceed 30 meters (100 feet) in depth.

- ***Origin of rock on the surface of Nisqually Glacier:***
  The glacier begins as a thick accumulation of snow and ice at the south edge of the summit crater. Avalanches fall from nearby rock walls and supply additional snow and rock to the glacier. In summer the ice melts on the lower mountain, but the rocks are left behind and accumulate on the surface, year after year. At thicknesses less than 2.5 centimeters (1 inch), small rock debris on the glacier enhances ice melt; rock debris at greater thicknesses slows the melting. The result of this action is a rocky and uneven glacier surface that by late summer is brown to black in color.

- ***Glacier advance and retreat:***
  Climatic conditions control the amount of snowfall and melt and, thus, the dimensions of a glacier. When summer melt exceeds winter snowfall over a period of years, the terminus retreats. When snowfall over a period of years exceeds summer melt, the terminus advances. A convex terminus indicates ongoing advance, while a concave terminus indicates terminus retreat. At Mount Rainier, changes in glaciers' terminus positions typically take about one decade to become apparent. Because of this relationship between climate and terminus behavior, glaciers are indicators of climate change.

- ***The Nisqually River begins beneath the ice of Nisqually Glacier and becomes visible at the cave-like opening glacier terminus.***
  River water carries a substantial load of glacial flour, the fine-grained rock eroded from the glacier's bed. In winter, the glacier melts less and flows more slowly, resulting in a reduced rate of erosion. This causes noticeable differences in the cloudiness of the water between winter and summer.

Figure 29*—During summer, Nisqually River rapidly conveys melt water from glacier and winter snowpack. The flow diminishes in winter. USGS photo by C. Driedger.*

Discussion questions for Nisqually Vista viewpoint:

General observations of Nisqually Glacier:

◆ List some features visible at Nisqually Glacier. ***Glacier terminus, cave where Nisqually River begins, rock cover on glacier, crevasses, glacier moraines, vegetative trimlines, snowline and U-shaped valley. If you visit during summer or fall, observe that the snowline is now at a higher-elevation than in winter. Snow that remains on the surface at the end of the summer melt season might eventually transform into ice.***

Water and rock cycles:

◆ Encourage discussion of the water and rock cycles. Name processes in each that are visible from here. ***Rock Cycle—results of volcanism notable as lava flows, pyroclastic flows, and volcanic ash; erosion by rock fall and glacier; moraine building; and transport of rocks and sediment downstream. Water Cycle—cloud formation and potential precipitation during your visit, glacier formation, long-term storage of water as snow and ice, glacier melt, and river flow.***

Rock on the glacier surface:

◆ What is the origin of rocks that cover the glacier surface? ***Much of the rock debris originates as rock fall. Successive layers of snow bury the rocks. The snow metamorphoses to ice and flows to lower elevations. In the warmer temperatures of lower elevations, the ice melts and the rocks accumulate on the glacier surface.***

◆ Why is there a large amount of rock fall at Mount Rainier? ***Volcanic and glacial processes have produced large amounts of loose rock by tephra fall, pyroclastic flows, erosion from the rubbly tops of lava flows, and glacial action. The freezing and thawing of water in fractures within the rock causes additional rock breakage.***

◆ What effect will the rock have on the melting of the glacier? ***Rock insulates the ice when it exists at a thickness greater than 2.5 centimeters (1 inch) and enhances melt at lesser thicknesses. When ice melts, rock from within is left to cover the glacier surface.***

Glacier advance and retreat:

- What natural processes cause glaciers to lose mass? ***Melting, sublimation (from solid to gas), evaporation, and avalanching.***
- Explain how the glacier can flow continuously downhill and at the same time lose length by melting. ***The position of the glacier terminus advances down valley when, over a period of years, flow rate exceeds melt rate. The position of the glacier terminus retreats up valley when, over a period of years, the glacier melt rate exceeds its flow rate.***
- What evidence is visible of the present status of the glacier? ***At this writing in 2014, the glacier terminus is retreating, and the terminus has a characteristic concave shape, as compared to a convex shape during advance.***
- What evidence suggests that the glacier has been larger in the past? ***Moraines and trimlines show former heights of ice, and glacial striations (scratches) are found atop flanking rock ridges.***
- How can knowledge of former glacier dimensions help us understand past climatic conditions? ***Glaciers enlarge or shrink in size as a result of climate conditions and thus are sensitive indicators of the climate over a period of years.***

Nisqually River:

- What causes the cloudiness in the water that exits the glacier? ***Glacial flour.***
- Which substance is harder—glacial ice or rock? ***Rock.***
- Can glacial ice cut rock, or is there another mechanism which allows for the cutting of rock beneath a glacier? Explain your reasoning. ***Ice is softer than rock and will not scratch it. Rock that is encased within glacial ice scratches rocks at the bed of a glacier.***
- Explain how glaciers can help and hinder the growth of vegetation. ***Glaciers store water as ice and then release it as stream flow. Plants and animals use this water for survival. Areas that are recently deglaciated are not conducive to growth of vegetation because they lack favorable soil and environmental conditions. In the long-term absence of glacier ice, soils form and vegetation can flourish.***

Establishing a photo record:

- Ask students about what a photo record can reveal about glacier change. ***Changes in glacier dimensions.***
- Encourage students to begin their own photo record, and give them the opportunity to start a long-erm photo record at this viewpoint. Ask what methodology will provide the most consistency with repeat photography. ***During each visit, take photos from same location (GPS can help you maintain your photo stations); include landmarks in photographs; use same or similar camera lenses; make photographs in clear weather; keep your photograph collection well labeled and organized.***

Figure 30— *Alternating layers of lava and loose rock rubble are visible in eroded slopes of Mount Rainier. Some of the loose rock layers were emplaced by pyroclastic flows and others from the broken shards of rock from lava-flow tops. USGS photo by C. Driedger.*

Internal structure of Mount Rainier:

- Nisqually Vista is a grand place to observe lava layers that protrude from within Mount Rainier. Nearly every cliff is the formerly pasty interior of a lava flow that hardened into dense rock, and the overlying slope is its rubbly flow top. Glacial erosion and rockslides have cut into the stacks of lava, exposing them in cross section. The lava layers slope away from Mount Rainier's summit, showing that nearly all lava flows erupted from high on the volcano, and that successive flows built up the volcano. Preservation of the loose rubble bands and the parallel layering show that the lava flows erupted in quick succession. In some places, careful observers may see places where higher layers cut across and terminate lower ones. These situations represent erosional breaks during which lava either did not erupt from the volcano or flowed to other parts of the volcano long enough that erosion could incise its slopes. Subsequent eruptions then buried those eroded surfaces.

End your field trip by completing the loop trail.

- During an in-class review of your hike, analyze any data collected and look at the photographs. Post-field trip review will promote retention of the material covered during this trip.

Option ❸ Alta Vista/Glacier Vista, Panorama Point, Myrtle Falls Hikes:

Logistics: 5 hours for complete trip

See hike options below. If departing from the main (upper) parking lot next to the Jackson Visitor Center, use the central trailhead (the grand granite staircase engraved with the John Muir quote) for access to these trails and nearby Myrtle Falls. For rubbings of glacial striations, bring a compass, tracing paper and pencils.

Note to teachers about trail safety:
Speak with staff at the visitor center to obtain an accurate assessment of current trail and weather conditions before embarking on a trip to Glacier Vista or Panorama Point. The trail offers dramatic vistas of subalpine wildflowers, a close-up view of Mount Rainier and Nisqually Glacier, and, on a clear day, views of Mounts St. Helens, Adams, and Hood. All hikers must remain on established trails.

***Figure 31**— Visitors hike the Skyline Trail with Mount Rainier and Nisqually Glacier as a backdrop. USGS photo by C. Driedger.*

Journey Back in Time-continued . . .

Features of Interest—(described thematically on pages 42 and 47)

1. Nisqually Glacier
2. Glacial geology
3. Lava and pyroclastic flow layers
4. Regional sources of volcanism

Hike Options

These trails offer dramatic vistas of subalpine wildflowers, a close-up view of Mount Rainier and Nisqually glacier, and, on clear days, Panorama Point and the Skyline Trail offer views of Mounts St. Helens and Adams as well as Rainier. Rather than a stop-by-stop description, this guide provides general information about features visible along all the trails noted. Refer also to the map in figure 19.

A. *Alta Vista:*

Alta Vista offers a view of Mount Rainier, rocks of Paradise Lahar, and tephra layers. Hike 2.7 kilometers round trip (1.7 mile) to Alta Vista for a regional view of Mount Rainier and the Paradise Ridge area.
1.25 hours—Average hiking time
Relevant descriptions in this field trip guide: general descriptions in the Nisqually Vista Loop Trail section.

B. *Glacier Vista:*

Glacier Vista offers a picturesque view of Mount Rainier, Nisqually Glacier, lava layers and fragmental volcanic deposits, boulders from lahars on ridge, and tephra layers. Round-trip distance from visitor center is approximately 4 kilometers (2.5 miles).
2 hours—Average hiking time
Relevant descriptions in this field-trip guide: general descriptions in the Nisqually Vista Trail section.

C. *Panorama Point:*

For hikers with proven ability to walk safely in challenging conditions, continue on to Panorama Point, 6.5 kilometers (4 miles) round trip from Paradise with 520 meters (1,700 feet) elevation gain. Enjoy a grand panorama of Mount Rainier and surrounding terrain.
3 hours—Average hiking time
See descriptions in A and B, plus glacier description in the Nisqually Vista Trail section.

D. *Skyline Loop/Golden Gate Trail options:*

Make a loop via the Skyline and Golden Gate trails (round trip of 6 kilometers or 4 miles). For a longer loop, hike the entire Skyline Trail, at 9 kilometers (5.5 miles) round trip.
3 hours—Average hiking time on Skyline and Golden Gate trails
4.5 hours—Average hiking time on Skyline Loop trail
See descriptions in A and B, plus the Nisqually Glacier description in the Nisqually Vista Trail section.

E. Myrtle Falls:

Consider taking the paved trail to picturesque Myrtle Falls. This trail (round trip 1.6 kilometers or 1 mile), leads the hiker over terrain underlain by deposits of two lahars and volcanic ash from Mount Rainier and Mount St. Helens. Elevation gain is 60 meters or 200 feet.
45 minutes—Estimated hiking time
Relevant description: Myrtle Falls

Background—features on Paradise Trail:

- ***All of the trails listed in the above options traverse Paradise Ridge, where early lava flows were confined by ice-age glaciers, then overrun by younger glaciers and lahars.***

  Around 40,000 years ago, the Ricksecker Point and Muir Snowfield, and earlier lava flows advanced down the broad crest of a rock ridge, confined by the flanking ancestral Nisqually and Paradise River Glaciers. Later, the glaciers enlarged, overtopped the ridge, and scoured away the lava's original rubbly top. The present Nisqually and Paradise Glaciers are now dwarfed by lava flows they had once confined. We know these lava flows as Paradise, Rampart, and Mazama Ridges. Along the trail the surface of the lava flow is widely mantled and concealed by tan, gray, and black boulders and sandy sediment of the Paradise lahar.

Background—lava layers:

- ***All trail options offer views of lava flow and pyroclastic flow layers.***

  The layered rock cliff directly across the Nisqually Glacier from Glacier Vista at 1,930 meters (6,340 feet) elevation affords a close view of lava flows and their rubbly tops (figure 32), as well as a small pyroclastic flow that was so hot when it came to rest that its ash and rock particles sintered or welded together and produced hard rock. Pyroclastic flows are fast moving avalanches of hot volcanic ash, lava fragments, and sometimes pumice that usually form during explosive phases of eruptions. On glacier-clad volcanoes like Mount Rainier, most pyroclastic flows traverse and melt snow and glacial ice. This both cools the pyroclastic flow and adds water, thereby transforming it into a lahar that can then travel long distances from the volcano. The pyroclastic flow across the Nisqually Glacier at least partly escaped this fate and is exposed about three-quarters of the way up the rock buttress as a low cliff band that slopes down to the left (south). This cliff has a sandy, brownish hue, distinct from the grayer and more closely fractured lava flows, and is overlain and underlain by sandy slopes that are parts of the pyroclastic flow that were insufficiently hot to weld when the flow came to rest. This pyroclastic flow erupted about 90,000 years ago immediately before an eruption of a large lava flow that caps Mazama Ridge and descends into Stevens Canyon to the southeast of Paradise.

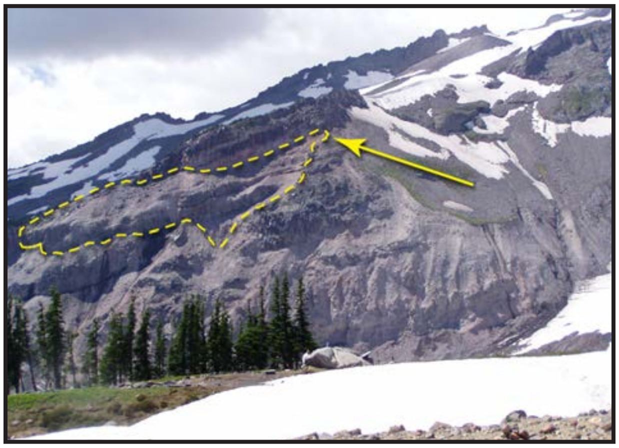


Figure 32— *Alternating layers of lava and loose rock rubble from pyroclastic flows are visible on the west side of Nisqually Glacier. Arrow shows welded pyroclastic flows. USGS photo by C. Driedger.*

Background—glacial striations:

- ***Glacial striations along the trail near Glacier Vista indicate the passage of ice.*** This is an ideal location to observe evidence of past glacier movement over Paradise Ridge. Glaciers commonly polish bedrock and boulders that face uphill, and break the rock on the downhill side. Coarse rocks that moved over the bedrock gouged scratches that are called striations. Finer grained rock carried by subglacial water polishes the bedrock and gives it a lustrous finish called glacial polish.

Figure 33— *Glacial striations are visible on bedrock surfaces along the trail between Paradise and Panorama Point. USGS photo by C. Driedger.*

Discussion questions where glacier striations are visible:

◆ Explain how the ice contributes to the development of these striations. ***Ice alone is too soft to scratch rock. Rocks embedded in moving ice at the base of the glacier scratch the bedrock.***

◆ Why does some rock appear rounded and polished? ***Finergrained rock debris carried in subglacial water can polish the bedrock and make a lustrous finish called glacial polish.***

◆ Use the striations to determine the direction of ice movement. ***In most locations, ice moved in a generally southwesterly direction.***

Experiment—mapping glacial striations:

Watch for glacial striations along your route. Use a compass to determine the direction of glacier movement at each location. Record the directions that ice traveled on a map. Do a pencil-and-paper rubbing of the striations at each mapped location. Are the striations the same everywhere? This can be done without leaving the trail.

Background: Skyline Trail

- ***Skyline Trail ascends on to 250,000-year-old lava flows.***
  Just above Glacier Vista the trail ascends steeply, commonly across snow, and then cuts back and up across a fractured lava outcrop. This outcrop is lava that erupted about 250,000 years ago during a period when Mount Rainier was especially active. This and similar aged lava flows form the substrate over which the Ricksecker Point and Muir Snowfield lava flows descended. This lava flow also forms Panorama Point, as well as the broad basin below Pebble Creek.

Figure 34— *Blasted rock outcrop in 250,000 year-old lava flow on the Skyline Trail. USGS photo by C. Driedger.*

Background: Panorama Point

- ***Panorama Point is a prime viewpoint on the Skyline Trail.***
  Panorama Point offers a grand vista of volcanic terrain of a variety of ages and origins. You stand on a 250,000-year-old lava flow from Mount Rainier, which is flanked on the downhill side by the 40,000-year-old Ricksecker Point lava flow. Upturned layers of the Columbia River Basalts that erupted from fissures starting about 17 million years ago form some of the horizon to the east. At middle distance and to the south rises the Tatoosh Range, the roughly 17-million-year-old mass of magma that rose into Earth's crust and cooled slowly. In the distance to the southeast, the eroded volcanic rocks of the 2-million-year-old Goat Rocks volcano appear as high terrain. On the horizon on a clear day, you can see the young stratovolcanoes—Mounts Adams, Hood, and St. Helens. Behind you to the north soars Mount Rainier. While at Panorama Point view the sign which points out additional features.

  Return to the visitor facilities by retracing your steps or by completing the loop trail, either by the eastern leg of the Skyline Trail or the shorter Golden Gate Trail.

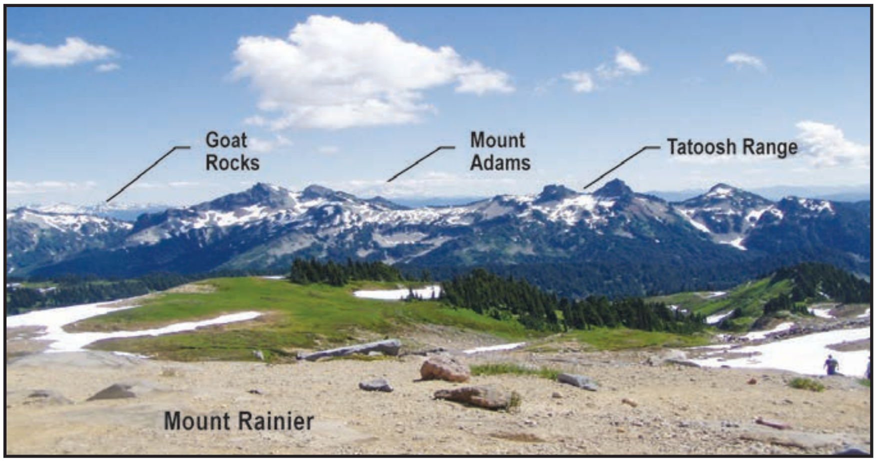


Figure 35 —*The view southward from Panorama Point. USGS photo by C. Driedger.*

Discussion questions for Panorama Point:

- At this viewpoint, name some of the visible geographic features that contain igneous rocks. ***Mounts Rainier, Adams, Hood, and St. Helens and Goat Rocks, Tatoosh Range, and Columbia River Basalts on the eastern horizon.***
- Indicate to students that volcanoes have erupted many times in this region. Ask them what this fact suggests about potential for future eruptions. ***Volcanism has modified the landscape of this region for millions of years, and there is every reason to believe that volcanism will continue into the future.***
- Investigate the rock cycle with your students. Choose one of the features noted above—one of the large volcanoes, the Tatoosh Range, or the Columbia River Basalts. Ask students to trace the path of the rocks that now comprise that feature. Invite them to hypothesize about the eventual destination of the rocks over geologic time. ***For the large volcanoes and for the Columbia River Basalts, rock originated as magma within the Earth, and then erupted and flowed on to Earth's surface. For rocks of the Tatoosh Range, magma rose into the crust but never reached Earth's surface. The rocks cooled slowly and eventually were exposed by weathering and erosion. Today, weathering and erosion by stream water, ice, and mass movements are wearing down the slopes of these features and transporting rock fragments towards the Pacific Ocean.***
- Snow patches can persist throughout the summer on Paradise Ridge. Discuss with students how long-lasting snow patches can affect the lives of animals and plants. ***Snow patches slow the seasonal growth of plants, but their melting provides water for plants and animals throughout the summer. Where snow patches remain throughout the summer, no plants grow.***

Discussion questions about water and rock cycles:

- Consider a stop at several points along the trail and listen. Can you hear the sound of running water? Where does the water originate? ***Water originates from the melting of snow and ice. What is the water's destination? The Nisqually River to the west, Paradise River to the east (which flows into the Nisqually River), and eventually to Puget Sound at Nisqually Reach.***

- List the processes of the rock and water cycles that are notable here. ***Rock cycle—results of volcanism are notable as lava flows, pyroclastic flows, volcanic ash, and lahars; and erosion can be seen as rock fall, moraine building, and transport of rocks and sediment downstream by the river. Water cycle—snowfall, long term storage of water as snow and ice, glacier melt, river flow, and cloud formation and potential precipitation during your visit.***

Background: Skyline Trail

- ***The Skyline Trail east of Panorama Point leads you across slabs of lava rock from the interior of a lava flow.*** Thousands of years ago, glaciers overtopped the ridge and scoured away the rubbly top of the Muir Snowfield lava flow, exposing this lava from the interior of the flow. The lava cooled, hardened and fractured into distinctive slate-like slabs.

Figure 36— *Lava flows fractured into plates are common in the vicinity of Panorama Point. USGS photo by C. Driedger.*

- ***The deglaciated area once covered by Paradise Glacier is visible to the east.*** From Panorama Point the hiker gets a distant view of recently deglaciated and barren terrain formerly covered by Paradise Glacier. Our generation is not the first to appreciate the Paradise Glacier area. Historically the Paradise Glacier ice caves were the principal visitor attraction on this side of the mountain. Early twentieth century visitors watched in dismay as the Paradise Glacier separated into upper and lower sections and the lower section became no more than an isolated stagnant ice mass. The once famous ice caves exist now only in memories and photographs, but a visit to the deglaciated area reveals a fascinating landscape of abandoned stream channels, glacial polish, striations, and chatter marks—the small curved fractures in the bedrock akin to marks made by a carpenter as their chisel slips along a piece of wood.

Figure 37— *An impressive display of glacial features exists where Paradise Glacier once flowed. USGS photo by C. Driedger.*

- ***Skyline Trail loops to the east above a persistent steep snowfield in the headwaters of Edith Creek and then descends onto the crest of upper Mazama Ridge.***

The 90,000-year-old Mazama Ridge lava flow caps the ridge down to the area around Reflection Lakes and then drops into Stevens Canyon where it supports Bench Lake and a long ridge on the southwest canyon wall. Several routes can be taken back to Paradise from upper Mazama Ridge, the shortest being the trail into Edith Creek from the Golden Gate (2.4 kilometers, 1.5 mile) return to Paradise. Further down Mazama Ridge, a side trip up the trail to the former Paradise Glacier ice caves region (2.4 kilometers (1.5 mile) roundtrip) affords close up views of the glassy ice-chilled edge of the Mazama Ridge lava flow (black shiny columns) and the terrain recently exposed by melting of the lower Paradise Glacier. This side trail departs from the Stevens-Van Trump historical monument near Sluiskin Falls.

Tephra from Mount St. Helens and Mount Rainier is visible in outcrops along the Skyline and Golden Gate Trails.

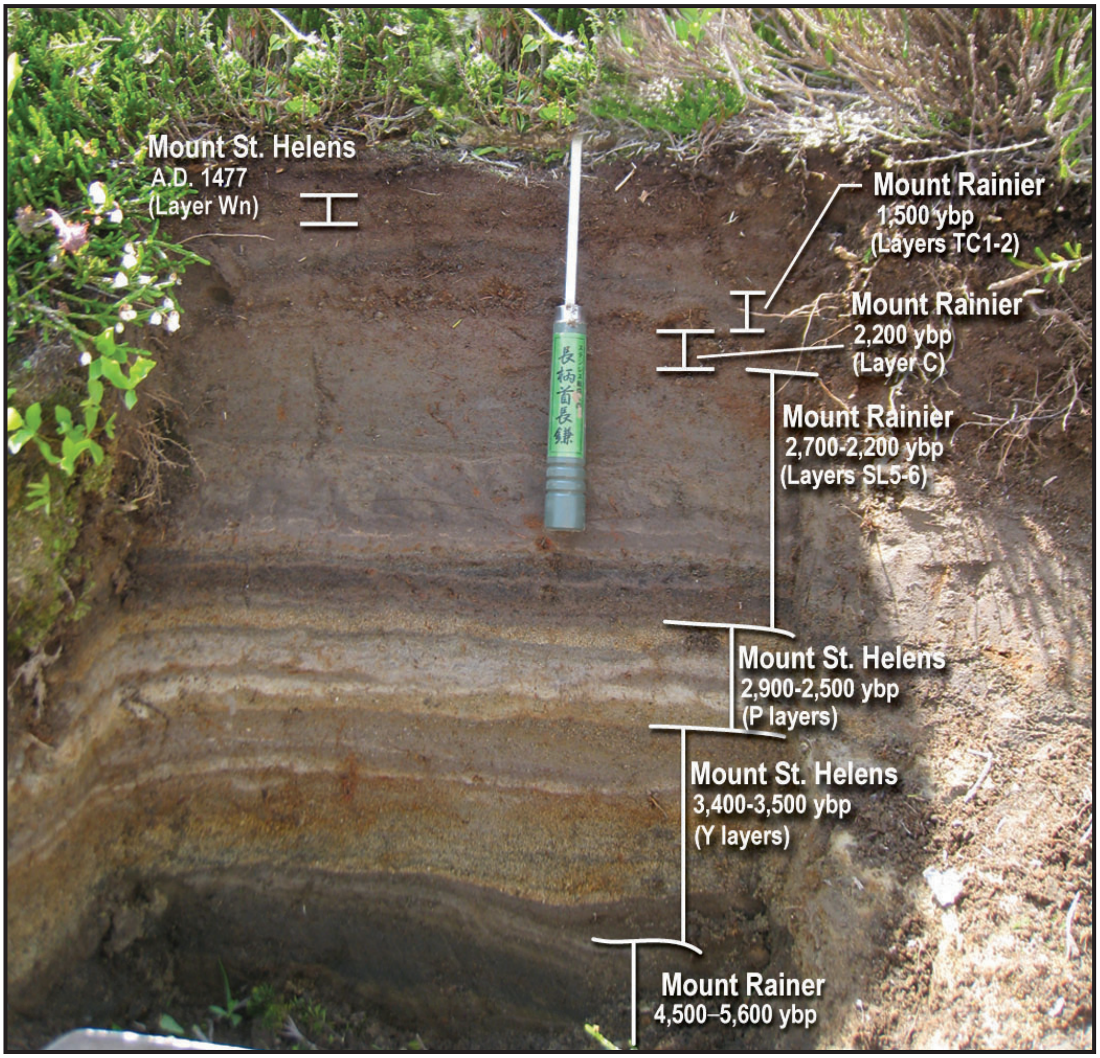


Figure 38*— Tephra layers identified by geologists are visible in trail cuts along the Skyline and Golden Gate Trails. USGS photo by J. Vallance.*

- ***Myrtle Falls offers a short walk and a picturesque view.***
  Walk on the side trail toward the base of the falls for a spectacular view of Edith Creek as it tumbles off the eastern edge of a cliff of Tatoosh granodiorite, with Mount Rainier as backdrop. The trail is underlain by rocky layers from two lahars and crumbly volcanic ash from Mount Rainier and Mount St. Helens.

Figure 39— *Myrtle Falls with Mount Rainier in the background. USGS photo by C. Driedger.*

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