PART II: ROAD GUIDE TO THE GEOLOGY OF THE MOUNT RAINIER AREA

LEG A: WESTERN APPROACH

Tacoma to Paradise via State Routes 7 and 706 and the Nisqually River valley

by Patrick T. Pringle and Elizabeth S. Norman*

This historic route follows much the same path as the original 'Road to Paradise', the first highway to the alpine meadows of Mount Rainier, constructed in 1916. The 49-mi (78 km) route rises from near sea level to about 5400 ft (1646 m) at Paradise (49 mi or 78 km) (Fig. A-1). The highways from Interstate 5 (I-5) to the beginning of this road log at the junction of State Routes (SRs) 7 and 702 traverse the gently rolling Puget Lowland, mostly on glacial till or outwash with isolated large boulders called erractics. Within a mile (1.6 km) after its junction with SR 702, SR 7 cuts through the valley of Tanwax Creek, a 'cross valley' cut into Vashon glacial drift. The road then descends through older deposits, including Pleistocene-age lahars from Mount Rainier and the underlying grayish Mashel Formation sediments of Miocene age, before crossing the Ohop Valley, a broad former glacial spillway. It then enters the Cascade Range near La Grande.

From about Tanwax Creek to as far east as Eatonville, the highway passes over a landscape that was modified by at least one large, late-glacial flood whose spillway was more than 6 mi (~9.5 km) wide. From the Ohop Valley east, this leg generally follows the Nisqually River valley, whose broad upper reaches formerly held large valley glaciers that extended from an ice cap in the Mount Rainier area during the Ice Ages. Coal-bearing sedimentary rocks of the Puget Group (of Eocene age) and volcanic and intrusive rocks of the ancestral Cascade Range (Eocene to Miocene in age) are visible en route between the Ohop Valley and Mount Rainier National Park.

During the past 12,000 years, many lahars have flowed down the Nisqually River valley from Mount Rainier. Some of the enormous lahars and their associated floods buried forests as far downstream as Puget Sound (although in areas outside Mount Rainier National Park, they remained within the confines of the Nisqually River valley).

About 13 mi (21 km) east of Elbe, the road reaches the Nisqually Entrance to Mount Rainier National Park. The landscape changes dramatically as you drive onto the south flanks of Mount Rainier volcano through ancient forests of enormous trees, across rushing glacier-fed rivers, through a ghost forest killed by debris flows at Kautz Creek, and along enormous ridges of lava and fragmental debris from volcanic eruptions.

The glacially carved canyons within Mount Rainier National Park offer spectacular views at every turn of the road, and the vegetation changes dramatically, both as the road climbs into the timberline environment and during the progression of the seasons.

Distances along the route are given in miles, followed by kilometers in italics. If you take any side trips, you'll have to keep track of and add those miles to all the remaining mileages in the leg. Having a pencil and paper handy, and even a calculator will be helpful.

Mileage

0.0 *0.0* This leg of the field guide starts on SR 7 at its intersection with SR 702. This location is about 21 mi (34 km) south of the SR 7 junction with SR 512. To get there from I-5, take SR 512 east at I-5 Exit 133, then go south on SR 7. Or, drive east on SR 510 from I-5 Exit 111 (near Olympia), and go about 26 mi (42 km) east via Yelm and SRs 510, 507, and 702. The junction of SR 7 and 702 is about 10 mi (16 km) east of the SR 702 turnoff at McKenna. From this point continue south on SR 7. Or, take an alternate trip via Eatonville (Leg N, p. 159) that rejoins SR 7 about 15 mi (24 km) from here along this leg.

0.1 *0.2* Milepost (MP) 36.

1.8 *2.9* Cross Tanwax Creek.

2.6 *4.2* On the east (left) side of SR 7 about 2.6 mi (4.2 km) north of Stringtown Road, a resident has arranged Stonehenge-like monoliths of large dark rocks (Fig. A-2). Boulders like these are commonly scattered on some parts of the Vashon Drift plain in this area; they are mostly andesite, but there is some granodiorite and other rock types. They were deposited by one or more great floods of water and debris that originated in the Cascade Range—the source area of the andesitic and granodioritic rocks—at a time when the Vashon ice sheet had receded somewhat from its maximum position, but before the Ohop valley was cut to its present depth by glacial meltwater. The catastrophic flood(s) was initiated when glacial Lake Carbon (Fig. A-3), an interconnected network of lakes dammed by the Puget lobe near the present canyon of the Carbon River south of Carbonado, suddenly drained (Pringle and others, 2000a; Goldstein and others, 2002). A landslide blocked the spillway, located along Fox Creek in the Cascades about 4.5 mi (7.2 km) southwest of Carbonado, and when it was breached, its debris probably augmented the flood. The southwest-trending valleys downstream in this area, such as that of Tanwax Creek, were in-

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Figure A-1. *(right)* Geologic map for Leg A (four consecutive panels). The geology was adapted from 1:100,000- and 1:500,000-scale digital versions of Schasse (1987a,b) and Schuster, 2005) and has been draped over a shaded relief image generated from 10-m elevation data. The leg maps were constructed using source-map data whose scale is smaller than the leg map scale, thus minor exposures may not appear on leg maps. The numbers in diamonds indicate mileposts. The map explanation is on the inside back cover.

cised by this flood. You will be crossing the floodway channel between MP 36 and MP 27.

3.1 / 5.0 Stringtown Road.

4.0 / 6.4 The road descends to the floor of the Ohop Valley, a major outwash channel that was carved by torrents of meltwater during the retreat of the Puget lobe of the Vashon ice sheet. Along this stretch of road, bouldery Vashon Drift sits on discontinuous older Pleistocene alluvium, including ash from Mount St. Helens and lahar(?) deposits from Mount Rainier (Fig. A-4). These deposits, in turn, rest on unconsolidated sediments of the Miocene

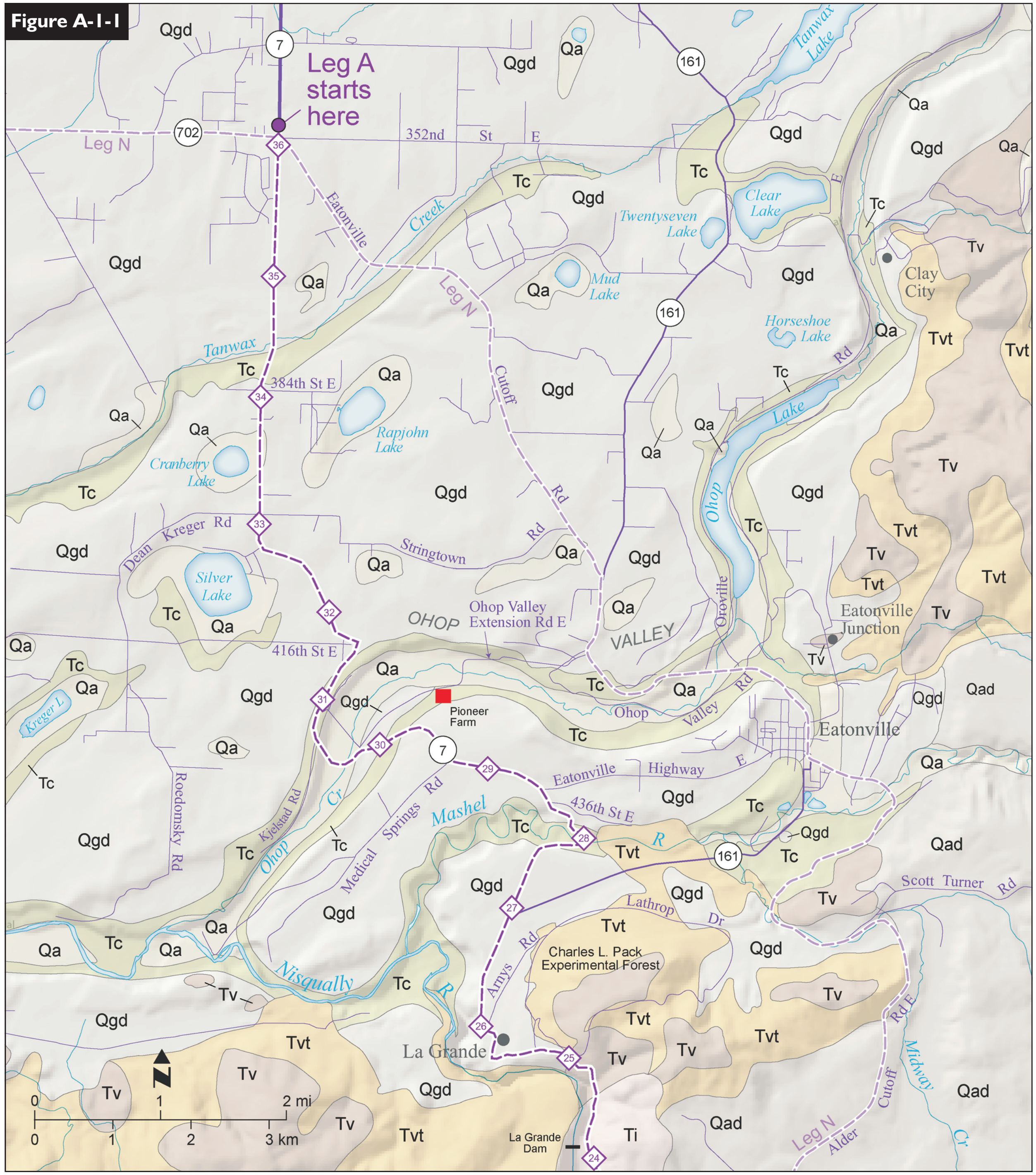


Figure A-2. Abundant andesite boulders at 'stonehenge' visible from SR 7. Boulders of andesite and granodiorite are strewn like glacial erratics across the glacial drift plain from Tanwax Creek to the Mashel River. These boulders were apparently deposited when drainage from a glacial lake in the vicinity of the Carbon River canyon was temporarily dammed by an earthflow of Lily Creek Formation volcanic debris. The dam breached, and the flood incorporated boulders and cobbles of andesite from the landslide, depositing them tens of miles farther downstream.

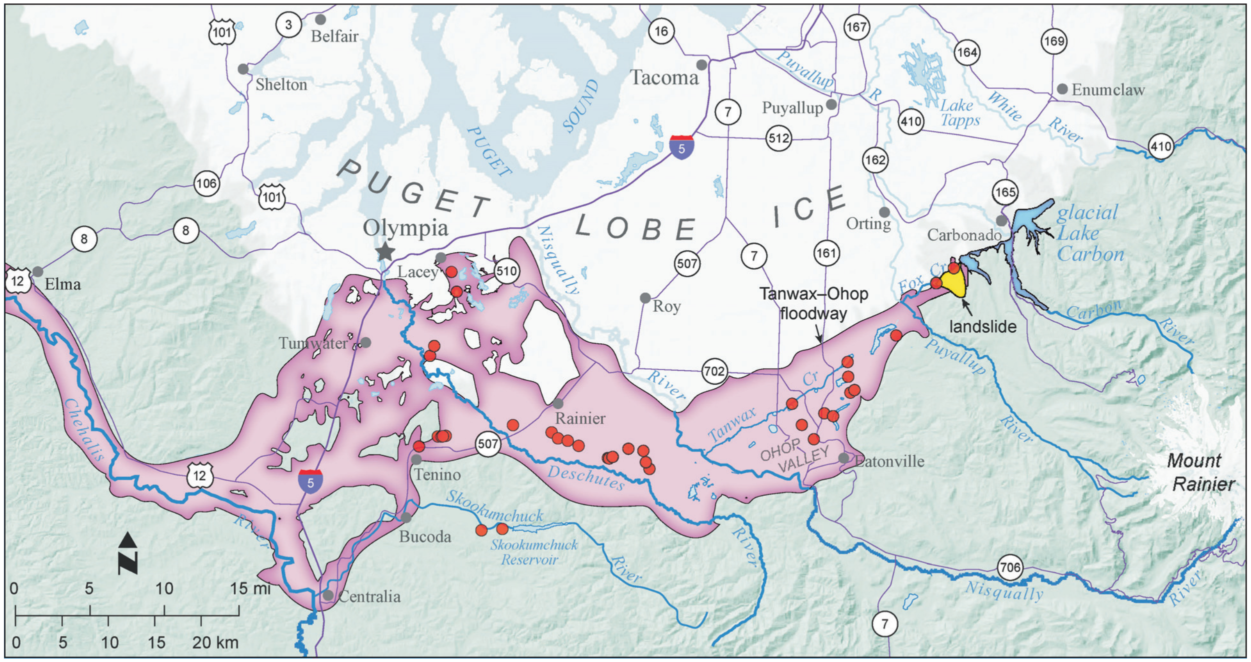


Figure A-3. Shaded relief map of the area that may have been inundated by the Tanwax Creek–Ohop Valley late-glacial flood (area shaded pink), showing the glacial flood channels cutting southwest and west across the generally north–south fabric of the glacial fluting and drumlins (not visible at this scale). Also shown are the Puget lobe of the continental ice sheet (area shaded light blue), the earthflow (yellow) that blocked the Fox Creek glacial spillway, and glacial Lake Carbon (dark blue), which was likely one of an network of interconnected ice-marginal lakes that drained catastrophically. Red dots are some of the locations of larger andesite and granodiorite boulders or boulder fields deposited by the flood. Further study may show that other drainages to the south of the pink area and not shown on this simplified map were also affected by the floods.

Figure A-4. Professor Barry Goldstein (left) and two students examine rocks from a Mount Rainier lahar deposit (lower layer) underlying Vashon(?) till along the west side of the Ohop Valley (SR 7). The buff-colored blobs above their heads are megaclasts, boulders of fragmental debris suspended in the matrix of the lahar deposit.

Figure A-5. Snow-laden Mount Rainier, 25 mi (40 km) to the east, from an informal pullout along SR 7 slightly east of the Mashel River. Even within a day of a snowstorm, bare rock exposed near the tip of the young summit cone at Columbia Crest provides evidence of the volcano's active geothermal system.

Mashel Formation, visible on the west (right) side of the road as you descend. The Mashel Formation consists mostly of fluvial and some lacustrine deposits that contain abundant pumice and other volcanic rocks. The pumice has not been studied, so its source and age are not yet known. The massive bouldery deposit capping the west valley wall surface is probably Vashon till.

5.7 *9.1* Cross Ohop Creek.

5.9 *9.5* Pioneer Farm tourist area, about 0.7 mi or 1.1 km northeast of SR 7 on Ohop Valley Road East.

6.1 *9.8* MP 30.

7.5 *12.0* Junction of SR 7 with the Eatonville Highway. Stay on SR 7.

8.1 *13.0* Cross the Mashel River.

8.5 *13.6* If weather conditions allow, west-bound visitors returning from Mount Rainier may have a glimpse of the mountain as they descend into the Mashel River valley (Fig. A-5).

9.0 *14.4* MP 27. Junction of SR 7 with SR 161 to Eatonville. Stay on SR 7.

9.4 *15.1* Charles L. Pack Experimental Forest. This experimental forest and research center is affiliated with the University of Washington. It is a 'working forest' that hosts a variety of research projects and meetings. The public can hike, bike, ride horses, or travel alone along a barrier-free self-guided trail.

10.0 *16.0* MP 26. Entrance to La Grande Dam, the lower of two dams on the Nisqually River. Alder Dam is visible on the right 2 mi (3.2 km) farther east along the road. The bedrock in roadcuts near this locality marks the entrance to the Cascade Range. From mile 10.8 to 11.1 (km 17.2–17.8), the rock photo by Dave Norman

Figure A-6. Andesite of Miocene to Oligocene age near Alder Dam overlook. View is to the north.

in the outcrops on the left (north) is andesite of Miocene to Oligocene age (Fig. A-6).

11.0 *17.7* MP 25. Viewpoint for La Grande Dam. The rocks north of the road near this viewpoint are andesites that were stained because of hydrothermal alteration along fractures. During this kind of low-temperature change, minerals such as hornblende and biotite are replaced by chlorite, calcite, and (or) other minerals. Here, the yellow color may be caused by iron minerals or pyrite transforming to the iron-oxide limonite.

12.6 *20.3* Viewpoint for Alder Dam. The dam marks the approximate maximum westward extent of a glacier that occupied the Nisqually River valley during the extensive Hayden Creek glaciation (~170–130 ka; Petit and others, 1999). No end moraine is visible in the Nisqually valley; however, Crandell and Miller (1974) identified Hayden Creek till north of the valley near here and a Hayden Creek end moraine southwest of Mineral Lake, about 9 mi (14.4 km) to the southeast.

Alder Dam was completed in 1944. The dam is 330 ft (100.5 m) tall, 1500 ft (457.2 m) long, and 120 ft (36.6 m) thick at the base while only 15 ft (4.5 m) thick at the top (Coombs, 1989). It can generate 50,000 kilowatts of electricity.

The 7.5-mi (12 km)-long Alder Lake is a fairly small impoundment, and its storage capacity becomes smaller annually as sediment from Mount Rainier forms a delta at its east end. Based on a

photo by Dave Norman

Figure A-7. Columnar jointing developed in Miocene basaltic andesite that contains visible plagioclase crystals. View is to the north near Elbe.

1985 resurvey, the lake held about 286 million m³ (374 million yd³) of water at its 'normal' pool level, and its maximum capacity was about 301 million m³ (394 million yd³). Therefore, less than 14.6 million m³ (19.1 million yd³) of storage would be available, should a lahar enter the reservoir. One

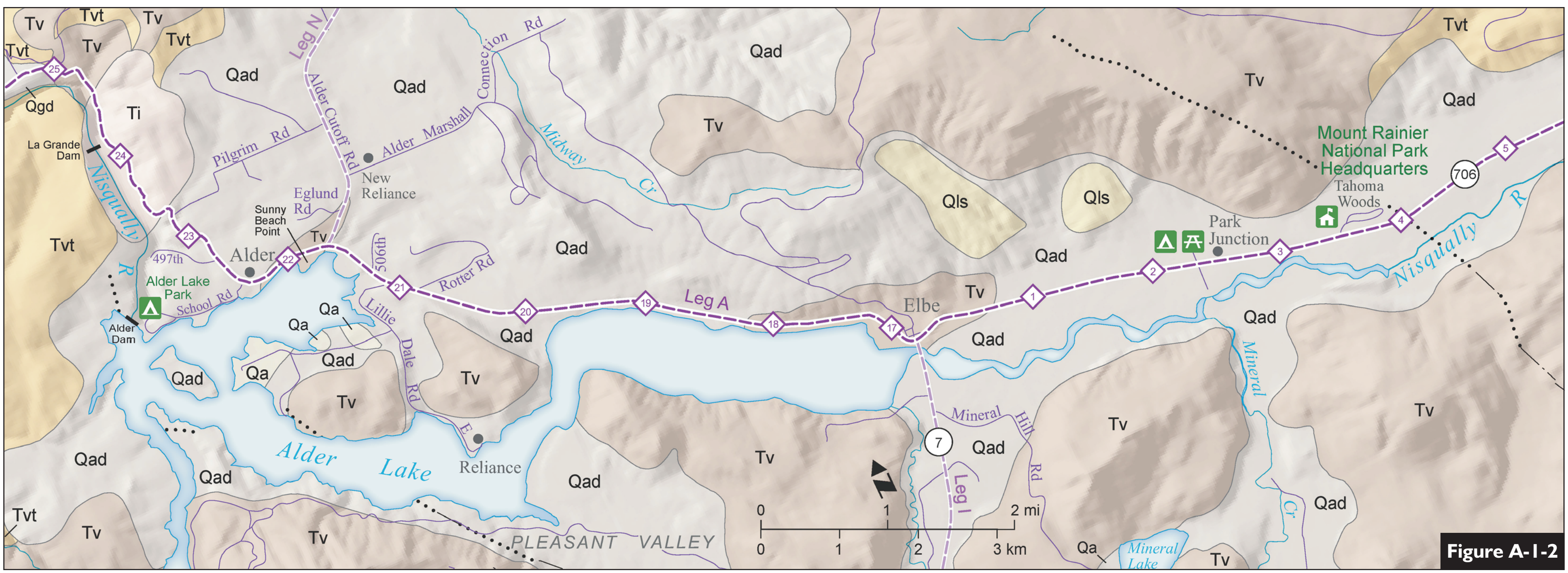


Figure A-1-2

Longmire Springs

by Rebecca A. Christie and Katherine M. Reed

Some History

In 1883, the story goes, guide James Longmire's hobbled horses wandered off from his base camp and 'found' mineral springs, for which Longmire soon filed a mineral claim under the provisions of the Federal Placer Act. In 1885, Longmire constructed a rough trail to the springs and opened a small hotel.

By 1896, Longmire and local native workers completed a dirt road from Ashford to the springs that was good enough for stages carrying visitors to traverse. Daily stages were operating on this route by 1909. To get to the springs, one could also take the Northern Pacific Railroad from Tacoma to Yelm and travel from Yelm to Longmire on saddle horses. Another rail day-trip route was from Tacoma to Ashford, thence to the springs. In 1890, round-trip passage, including board, cost $12.00; board and treatment at the springs was $8.00 per week (Martinson, 1966). Car travel to the park began in 1907; before long, automobiles brought far more visitors than the trains.

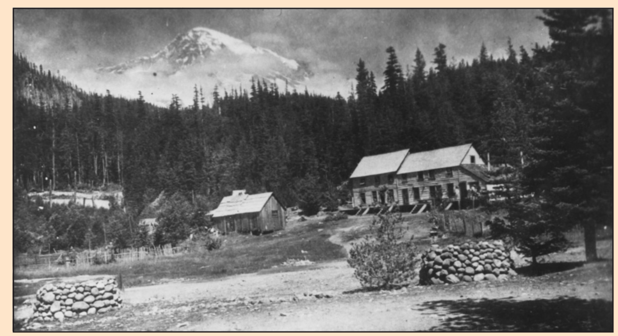
A competing comfortable hotel, the National Park Inn, was built by the Tacoma and Eastern Railway Company (also called the Tacoma Eastern Railroad) in 1905–06. In 1908, the Longmires built another rustic hotel and a tenting facility. The Longmire Springs Company leased land from the family for yet another hotel, the National Park Annex, which had replaced the original inn that burned in 1926; it was rebuilt in 1990. (See Allaback and Jacobson, undated, for more information.) Concerns about lodging prices and the condition of facilities led to a gradual eviction of the Longmires. The family sold the property to the federal government in 1919. Also in 1919 (*Seattle Post-Intelligencer*, July 19, 1919), the Rainier National Park Company arranged a lease until 1936 for Longmire Springs. By that time the park had moved its headquarters to Longmire. The first administration building (1916) has become the museum and visitors center. The structures in Longmire Historic Developed Area are historic landmarks; their "Rustic Style" was chosen to blend into the surroundings.

The Springs

An advertisement for Longmire's Medical Springs in the 1890 Tacoma newspaper, *Every Sunday*, claimed that the waters could cure "rheumatic pains, catarrah, piles, and other incurable afflictions". According to an early Park Service report, "Several kinds of mineralized waters spring from the ground on this tract and little care is exercised to prevent pollution. A large amount of this water has a temperature of 70ºF on reaching the surface. It is heavily charged with sulphur....Other waters are charged with iron, and still others are sweet, cool, and sparkling" (Reaburn, 1915). Another early report indicates the spring waters "range in temperature and mineral content from cold carbon dioxide (CO_2)–charged springs to hot sulphur-iron springs" (Glover, 1936, p. 72). David Frank (written commun., 2007) notes: "Although the springs have some sulfate content and precipitate some pyrite in aragonitic mud, they are primarily bicarbonate-chloride waters precipitating carbonates (calcite, aragonite, and some rhodochrosite). The springs also have relatively high concentrations of iron that contribute to the pyrite in the reduced environments (aragonitic mud), and iron oxyhydroxides in the oxidized environments (surface pools and streams)." There was actually no proven health benefit.

Of about 50 mineral springs identified in an early Park Service report in the area, two were developed: Iron Mike and Soda Springs, both enclosed in the 1920s. Iron Mike earned its name because of the iron content of the water and the iron-rust color of its deposits (U.S. National Park Service, 1934?). A National Park Service report dated 1934 reported that the temperature of the water in the springs was as high as 85°F (29°C). More recent studies (H. M. Majors, unpub. report, 1964; Korosec, 1979; Frank, 1985) found variation in the configuration of springs relative to earlier reports, probably as a result of water diversion and flooding by beaver dams and travertine deposits. Frank (1995) reported temperatures ranging up to 28°C, and flow to 0.1 liter/second (82°F and about 1.5 gallons/minute). Sustained maximum temperatures in springs he sampled were as high as 25°C. Travertine and tufa deposits line the warmer springs, with the most extensive travertine mound in the west central part of the meadow. The southeastern springs have 'moderate gas discharge' (possibly CO_2) but very little water flow, whereas the western springs have more flow and higher temperature (Frank, 1995). Symonds and others (2003) measured the gas content of Soda Spring in 1997–98 and found it to be 99.6 to 99.8 percent CO_2. Frank (written commun., 2007) adds, "The small springs in shallow depressions across the trail from Soda Spring are ones that have accumulated dead birds now and then, presumably from suffocation". (See also the "Ohanapecosh Hot Springs" sidebar on p. 125.) ■

Longmire Springs Hotel (later called the National Park Inn Annex) at Longmire circa 1916. View is to the northeast with Eagle Peak in the background. Courtesy of University of Washington Libraries, Special Collections, A. H. Barnes photo 433A.



Longmire Springs Hotel, probably built 1906, with the southeast flank of Mount Rainier in the background and enclosed springs. Courtesy of University of Washington Libraries, Special Collections, photo 'nps longmire cabins'.

concern is that this storage volume is probably not large enough to contain the most dangerous type of lahar, the clay-rich type that could occur if a sector of Mount Rainier collapsed without warning—an event that, although rare, has occurred at other volcanic mountains. Such a lahar, if large enough, could generate waves that would overtop the dam. However, geologists think it is most likely that precursory volcanic activity, such as increases in the number and size of volcanic earthquakes, would provide advance warning of eruptive activity and, with it, the greater potential for a lahar. If that happens, the reservoir could be drawn down at a maximum rate of about 0.3 percent capacity per hour, or more slowly if the area is already experiencing a seasonal flood event.

13.0 *20.9* MP 23.

13.5 *21.7* Alder Lake Park and Alder Dam. This side road leads about 1 mi (1.6 km) to the dam viewpoint and Boathouse Campground.

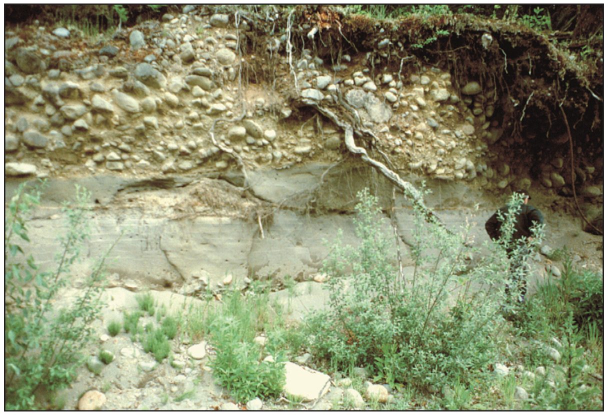


Figure A-8. USGS geologist Kevin Scott (right side of photo) examines an assemblage of bouldery lahars and finer grained lahar-runout deposits near National along the north bank of the Nisqually River. Radiocarbon ages on carbon found in these deposits show these lahars were likely produced during the Summerland eruptive episode at Mount Rainier, some time after the Round Pass mudflow (~2,600 yr B.P.) but before Mount Rainier C tephra (~2,200 yr B.P.). Each of several gray layers below the upper bouldery unit is a runout from a lahar.

14.1 *22.7* MP 21. On a fine day, Mount Rainier can be seen looming ahead.

14.2 *22.8* Sunny Beach Point. Andesite of Tertiary age crops out north of the highway.

14.4 *23.1* Junction of SR 7 with the Eatonville/Alder Cutoff Road (Leg N). Stay on SR 7. Alder Lake is on the south side of SR 7.

16.0 *25.7* MP 20. The sharp peaks of Sawtooth Ridge are visible ahead in the distance, showing layers dipping off to the south (right). The layers are rocks of the Ohanapecosh Formation, whose ages range from about 36.5 to 28 m.y. (Walsh and others, 1987). These rocks include volcaniclastic layers, as well as some lavas, and are cut by many intrusions of dacite and andesite.

19.2 *30.8* At Elbe, continue straight ahead on SR 706. SR 7 turns to the south here as Leg I (p. 137). The outcrop on the left near the junction exhibits columns developed in Miocene basaltic andesite that contains visible plagioclase crystals (Fig. A-7).

Nadeau (1983) reported that this area may be one of the oldest settlements along the river, first settled by the native tribes. James Longmire expanded on the trails the local peoples had used to create a trail to his resort near Mount Rainier. (See the "Longmire Springs" sidebar on p. 57.)

20.2 *32.5* MP 1.

22.1 *35.6* Just past MP 2, the road ascends a small terrace. Most of the valley bottom here is underlain by postglacial lahars from Mount Rainier, many deposited in the past several thousand years.

22.2 *35.7* MP 3.

22.5 *36.2* The Tahoma Woods area. Slightly before the access road to the Mount Rainier National Park administrative offices, the road ascends a small terrace. A stack of lahar and lahar-runout deposits, many of which were triggered during eruptive activity at Mount Rainier between about 2,600 and 500 yr B.P., is exposed along the Nisqually River near here. The lahars were not quite deep enough to have inundated this terrace, which is veneered by Evans Creek–age (22–15 cal yr ka) glacial outwash capped locally by loess (Fig. A-8).

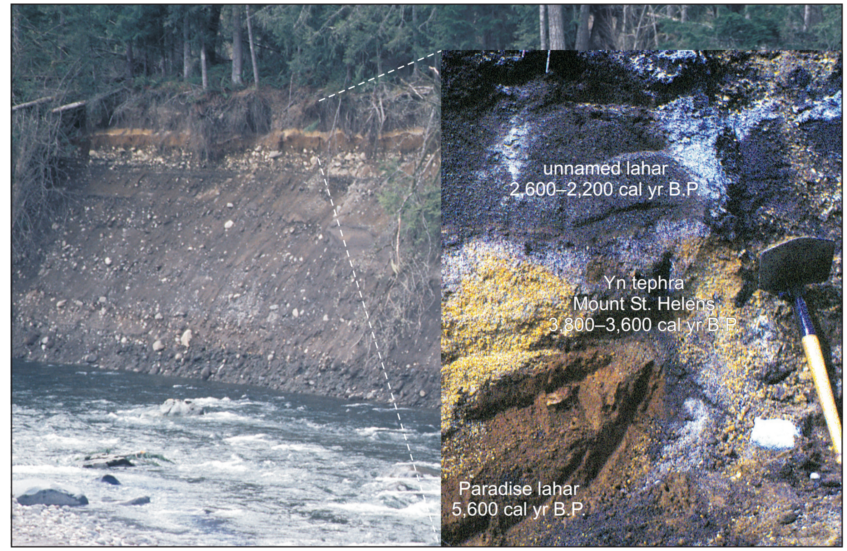


Figure A-9. A lahar of Summerland age is exposed at the Nisqually River bridge at National. The bank is about 25 ft (8 m) in height. The colored layers below the terrace surface (inset) are also exposed in a drainage ditch along the road about 200 ft (60 m) south of the bridge. They are, from bottom to top, the brownish Paradise lahar, about 5,600 cal yr B.P.; the yellowish Yn tephra layer erupted from Mount St. Helens about 3,800 to 3,600 cal yr B.P.; and the grayish unnamed lahar triggered by an eruption at Mount Rainier between 2,600 and 2,200 yr B.P. The trenching tool in the inset is about 18 in. (45 cm) long. View to the southeast.

25.3 *40.7* Forest Road (FR) 92 on the left gives access to the Mount Tahoma Trail System.

25.8 *41.5* **OPTIONAL SIDE TRIP:** Volcanic deposits at the bridge at National. The bridge was washed out in the flood of November 2006. This is a 2.6-mi (4.2 km) round trip on a bumpy gravel road to see evidence of an eruption at Mount Rainier that sent a wave of pumiceous sand far down the Nisqually River. Take 553rd Street (labeled "South District Access") at about 0.5 mi (0.8 km) to the Nisqually River. The deposit of at least one clay-poor lahar is exposed upstream of the bridge on the left (south) bank, where it is the thin gray top layer (Fig. A-9). That lahar deposit sits on a yellow Mount St. Helens pumice called the Yn layer (3.6 ka), which in turn rests on the reddish-brown Paradise lahar from Mount Rainier (5 ka). This sandy, Summerland-age lahar is just below the Mount Rainier C tephra (2,200 yr B.P.). Deposits of a 500-yr-B.P. lahar veneer the flood plain north of the bridge (Jim Vallance, USGS, oral commun., 2004). Near here, a 6- to 12-ft (1.8–3.7 m)-thick sandy gravel deposited by the Summerland-age lahar caps a terrace that is 60 ft (18 m) higher than this location, thus showing that the peak wave of the lahar was substantially higher than indicated by the deposit at this site. This minimum thickness is five times the recorded stage height (12.18 ft or 3.7 m) of the largest historic flood measured here on Feb. 8, 1996! A few hundred yards downstream of this bridge, the 2.6-ka Round Pass mudflow underlies the sandy lahar layer and contains many large trees that it uprooted in its passage from the flanks of the volcano.

The flood wave of the Summerland-age lahar was high enough to have buried trees at least as far downstream of Mount Rainier as McKenna, near Yelm, more than 35 mi (56 km) away, and no doubt it reached the Nisqually River delta. This lahar is an example of a clay-poor lahar. It probably began when a pyroclastic density current was erupted at the summit of Mount Rainier and collapsed on the mountain's flanks. Volcanic bombs having radial jointing have been identified in the lahar deposit (Figs. A-10 and A-11). As it flowed downslope, the current eroded glaciers, melted snow and ice, and incorporated enough sediment to generate a lahar. As the lahar traveled downstream along the Nisqually River, it gradually deposited sediment and added water to become a lahar runout. In this state of transformation, it likely still had the characteristics of a thick slurry, at least until it reached the Ashford–National area, where yard (meter)-size masses of unconsolidated, bedded Mount St. Helens pumice and soil were transported as intact blobs within the flow. A more turbulent, lower-concentration flow could not have transported so large a mass of loose sediment as a single block in this way.

Remember to compensate for the mileage (2.6-mi [4.2 km] round trip) along the side trip.

26.3 *42.3* Town of Ashford.

27.2 *43.7* MP 8.

29.3 *47.1* Kernahan Road becomes Forest Road 52 leading south to Packwood and US 12 in the Cowlitz River valley. It provides access to hiking trails such as the High Rock Trail, which provides an excellent view of Mount Rainier and Kautz Creek from the tip of a hogback ridge south of Mount Rainier National Park. From here to Goat Creek, you pass along tightly folded sedimentary rocks of the Puget Group, on the skyline north of the road). Buried trees were exposed along the Nisqually River in this reach by the record flood of November 2006 that temporarily closed Mount Rainier National Park. Near one location, the 500-year-old lahar, Summerland-age lahar, and log-bearing Round Pass mudflow deposits were lying atop a 2-ft (~0.5 m)-thick layer of Mount St. Helens Yn tephra, which in turn was sitting on a clay-rich, log-bearing lahar, possibly the Paradise lahar.

29.5 *47.4* FR 59, which leads north into the Glacier View Wilderness Area.

30.1 *48.4* MP 11. Cross Copper Creek 0.2 mi (0.3 km) east of the milepost.

31.4 *50.5* Goat Creek cascades seasonally over a debris fan of large boulders and cobbles. Debris flow deposits from this fan sit atop a deposit that is correlative with the clay-poor lahar exposed at National. From Goat Creek to the Nisqually Entrance of Mount Rainier National Park, you are driving in the Ohanapecosh Formation. Northeast-dipping beds of volcanic breccias and tuffs are visible just west of the park entrance.

32.8 *52.7* Mount Rainier National Park, Nisqually Entrance (elev. 2023 ft or 617 m).

33.2 *53.4* Braided channels of the Nisqually River here occupy the former site of the Sunshine Point Campground (Fig. A-12). The November 2006 flood re-

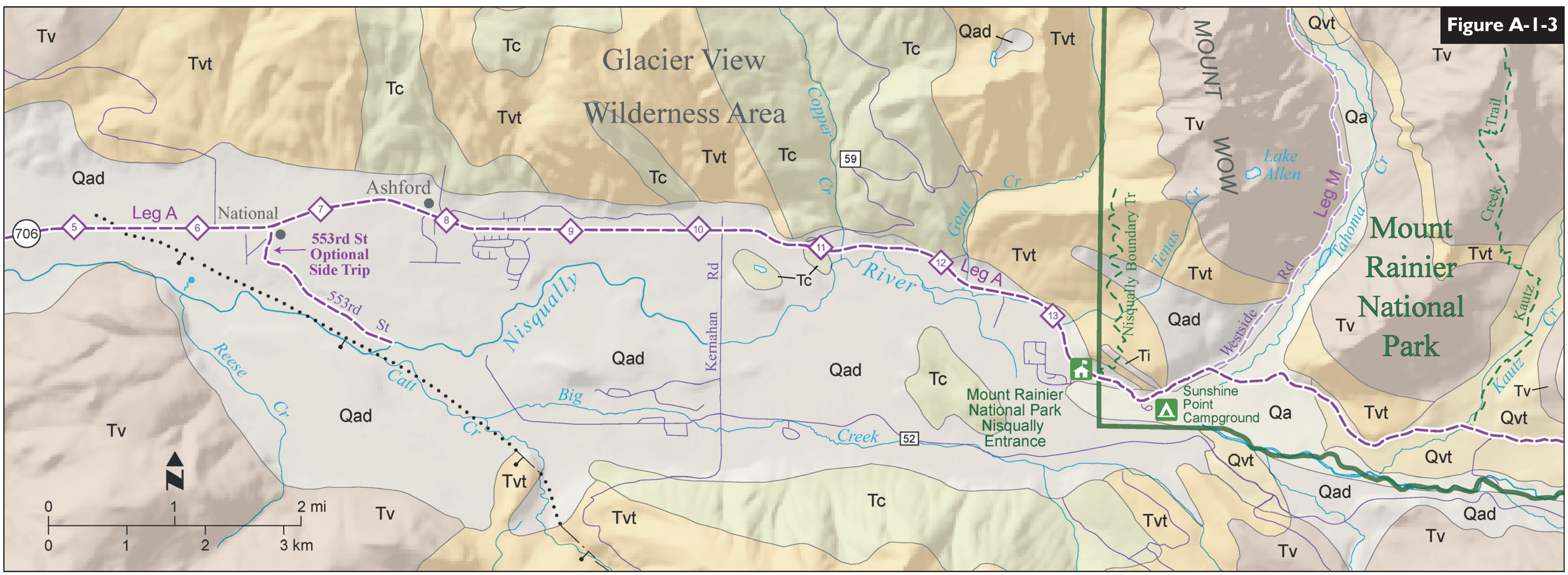


Figure A-1-3

Figure A-10. A breadcrust bomb, or prismatically jointed boulder, in a Summerland-age lahar. Such volcanic bombs are molten when erupted and cool rapidly, developing these radial fractures. (See Fig. A-11.) Trenching tool is about 18 in. (45 cm) long.

moved most of the terrace on which the campground sat. The outcrop on the left is Ohanapecosh Formation tuffs with blocks of andesite, as well as a pumiceous unit (Fig. A-13).

33.8 54.4 MP 1. Westside Road. Although this is one of Mount Rainier National Park's less traveled areas, it offers access to some excellent hiking destinations and places to view the effects of the glacial

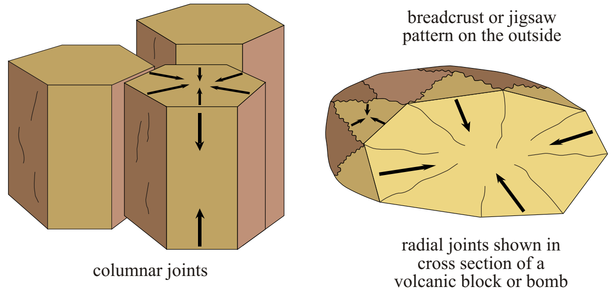


Figure A-11. Sketch of columnar jointing in a lava flow and prismatic or radial jointing in a volcanic bomb. Small arrows show the direction of contractions during cooling; thicker arrows show the direction of cooling. Joints are caused by contraction.

outburst floods of the 1980s and 1990s. For a description of the geology along Westside Road, see Leg M (p. 155).

34.0 54.7 The cobble bars near the bridge over Tahoma Creek are predominantly flood deposits from 1990 and later. Much of the material from the series of glacial outburst debris flows that began in 1986 was deposited farther upstream.

Continue east toward Kautz Creek.

35.3 56.8 An outcrop of basaltic andesite from Mount Rainier is exposed across from a pullout on the right (Fig. A-14).

36.2 58.2 Kautz Creek. Many tall snags near the Kautz Creek parking lot and observation point (north of the road and slightly east of the bridge) are remnants of trees that were killed by the damaging debris flow of Oct. 2 and 3, 1947 (Fig. A-15). North of the bridge, deposits of that debris flow and of previous lahars are exposed. The debris flow buried the old road with 20 ft (6 m) of rock and mud and temporarily dammed the Nisqually River (Fig. A-16). In the November 2006 storm, the creek radically changed its course 0.2 mi (0.3 km) eastward of its previous channel and has cut into the 1947 debris fan. (See the "Recent Geomorphic Evolution of the Landscape" sidebar, p. 52.)

USGS hydrologist Donald Richardson (1968) suggested that the 1947 debris flow was the result of intense downpours combined with the release of additional water from Kautz Glacier. Other outburst debris flows, considerably smaller than that

Figure A-12. Braided channels of the Nisqually River here occupy the former site of the Sunshine Point Campground. A small remnant of the campground is on the left. Taken September 2007.

Figure A-13. An outcrop of tuffaceous volcaniclastic rocks of the Ohanapecosh Formation near the Nisqually Entrance.

of the 1947 event, occurred at Kautz Creek during the summers of 1985 and 1986. Some of the shorter snags visible in the river are possibly part of older buried forests that predate the trees killed in 1947. Notice that some of the tree species (Douglas-fir and western hemlock) are decomposing much faster than others (western redcedar).

On clear days, the high cirque of Sunset Amphitheater is visible to the north from this viewpoint. This chiseled west face of Mount Rainier has been the source of many lahars.

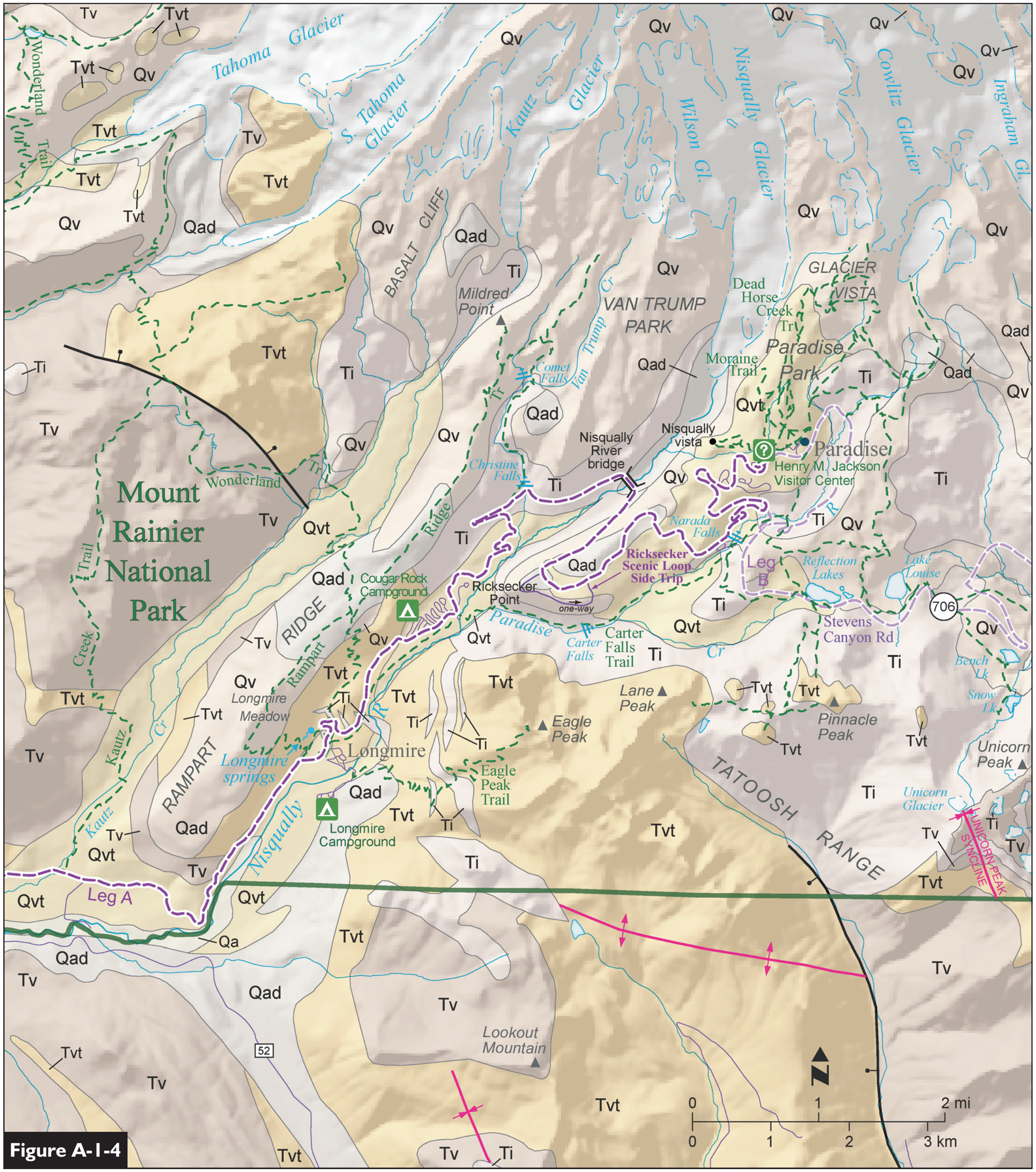


Figure A-1-4

photo by Dave Norman

Figure A-14. An outcrop of basaltic andesite from Mount Rainier, about 1 mi (1.6 km) west of Kautz Creek.

37.8 MP 5. View of the Nisqually River.
60.8

39.1 Longmire. (This is a good place to purchase de-
62.9 tailed maps of the park.) The museum at Longmire was the original park headquarters. Geologist Rocky Crandell (1971) found that both the right and left banks of the Nisqually River here had been inundated by lahars that post-dated Mount St. Helens Wn ash layer because the ash veneers older surfaces nearby but not the young terraces adjacent to the river here. That ash, which is 2 to 3 cm (0.8–1.2 in.) thick in this area of the park, was erupted from Mount St. Helens late in A.D. 1479 (or possibly early in 1480), so it is a useful marker bed for relative dating of recent deposits (Yamaguchi, 1983; Fiacco and others, 1993).

Crandell also noticed a relatively youthful forest and boulder levees on the south side of Longmire Meadow and, on the basis of the age of the oldest tree growing on the surface there, inferred that a lahar buried this portion of the right bank sometime before 1860. Boulder levees, which delineate the margin of a small debris flow deposit south of Longmire Meadow, separate trees of different ages and show that these lahars did not inundate the entire terrace. An excavation at the old Longmire gas station to remove its aging fuel tanks revealed a stump rooted more than 15 ft (5 m) below the surface that had been buried by a

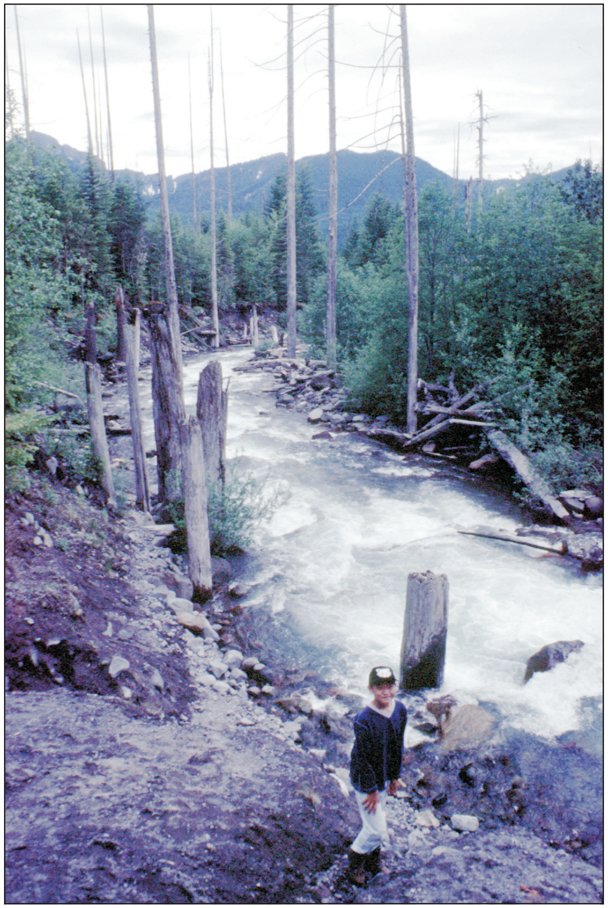


Figure A-15. Snags at Kautz Creek killed by the debris flow of Oct. 2 and 3, 1947. View is to the south from a bridge over Kautz Creek in 2001. The creek abandoned this channel during the great flood of November 2006 and cut a new channel into the 1947 debris fan about 0.5 mi (0.8 km) farther east.

thick cobble-boulder gravel. Tree-ring studies show that this tree died sometime after A.D. 1686—the tree lacked bark, so a precise year for its death could not be determined. The cobble-boulder deposit likely is older than the pre-1860 debris flow mentioned earlier. The ages of the oldest trees growing on a lahar deposit that caps the left bank of the river near here reveal that the deposit was laid down after A.D. 1479 but before about 1570.

The late-2006 flood damaged the Longmire sewage line and knocked down the power lines

Figure A-16. Aerial oblique photo of Kautz Creek (center) showing the extent of the 1947 debris flow. This glacial outburst event temporarily dammed the Nisqually River (right) and buried the old park road under 20 ft (6 m) of rock and mud. In the flood of November 2006, Kautz Creek shifted its course about 0.5 (0.8 km) to the east. Photo by Austin Post, USGS, taken Sept. 22, 1966

that crossed the Nisqually River. It also severely eroded the park facilities parking lot.

At Longmire Meadow, water at temperatures as high as 28°C (82°F) is discharged through and around low travertine mounds (Fig. A-17). These features are spectacular in the winter and early spring when their orange-red colors contrast with the snow in the surrounding meadow. The largest mound and highest temperatures are found in the west part of the meadow. National Park Service records refer to about 50 springs in existence in 1919 and 1920. Fewer than half that number have been documented in recent years, probably because of flooding by beaver dams. Temperature measurements show no significant change through most of the 20th century. Geologist David Frank, who has studied the hydrothermal system at Mount Rainier in detail, used 1983 measurements (temperature, chemistry, and discharge) of inflow and outflow streams at the meadow to estimate

Figure A-17. View from the Trail of the Shadows at Longmire showing an area of travertine deposition. The travertine is deposited by mineral-rich spring waters that emerge in this meadow. Oxidation of the iron-rich water produces the orange coatings of iron oxyhydroxide precipitates and bacteria. The base of Eagle Peak is visible in the distant background. For more information on Mount Rainier's mineral springs, see p. 57 and 123.

that Longmire springs provides 8 percent or less of the hydrothermal discharge from the park (Frank, 1985, 1995). Frank also analyzed the travertine mounds and found that they are composed mostly of calcite and aragonite and a small amount of rhodochrosite, a reddish carbonate mineral that contains manganese. Other carbonate minerals probably occur in small amounts. Some of the ponds around the mounds contain an oxygenphoto by Beth Norman

Figure A-18. Carter Falls from below the bridge. The falls, which cuts Tatoosh granodiorite, is about 1.3 mi (2 km) east of the Cougar Rock area on the Wonderland Trail.

poor, aragonitic mud with pyrite and a high dissolved iron content. Oxidation of the iron-rich water produces orange coatings of iron oxyhydroxide precipitates downstream of the meadow. (Learn more about Mount Rainier's hydrothermal system on p. 39.)

39.7 Wonderland Trail and parking area. The large out-
63.8 crop on the left is a slightly altered andesite of the
Ohanapecosh Formation.

41.3 Carter Falls Trailhead pullout on the right (Fig. A-
66.4 18) and a view of Ricksecker Point.

41.4 Lahar deposits near Cougar Rock Campground
66.6 and the former Nisqually River footbridge. Yellow
layer Yn tephra that was erupted about 3500 years ago from Mount St. Helens underlies two lahar deposits here. Layer Wn ash, erupted from Mount St. Helens late in A.D. 1479, mantles the surface in this area. Crandell (1971, p. 42) found a tree growing on the surface in which the oldest ring was aged at about A.D. 1180. Hemstrom and Franklin (1982) extended the minimum age of the terrace even further, to about 1000 years old, using ring counts of stumps on the same surface.

photo by Beth Norman

Figure A-19. Well-developed columnar jointing exposed on the valley wall of Rampart Ridge as seen from a bridge that crosses the Nisqually River. The andesite flow is dated at 370 ka (Sisson and Lanphere, this volume).

The footbridge (destroyed in 2003) was a good place to observe the thick, valley-filling lava flow that composes Ricksecker Point across the valley to the northeast. At one time it was thought that this flow and others like it were deposited in valleys, which were then rapidly incised adjacent to the resistant lava flow. However, Lescinsky and Sisson (1998) found glassy lithic fragments at the edge of the flow that indicated it had flowed into the valley along side of, and cooled next to, a large valley glacier. The edges of many other valley-filling flows look similar to this one, so geologists have concluded that it was not uncommon for lava to come to rest next to glaciers. (See Fig. 27 on p. 30 and related discussion in Leg B, p. 70, mile 8.8.)

For about the next mile, the road ascends in hairpin turns, passing by Evans Creek till plastered high on the valley wall and ending on a terrace of assemblage C lahars of Crandell (1971). Assemblage C is bounded by Mount St. Helens tephra layers Yn and Wn. The Nisqually River has both aggraded its bed and laterally eroded its banks upstream of Cougar Rock Campground since the mid-1990s, and bouldery deposits are now visible above the roadbed locally.

photo by Beth Norman

Figure A-20. This thick porphyritic andesite lava flow at Ricksecker Point is one of the youngest major lava flows at Mount Rainier. The flow has local platy jointing. View to the north.

43.3 Trailhead to Comet Falls and Van Trump Park. A
69.7 steep trail leads to these destinations. Those who
take the time to hike up to Mildred Point will be rewarded with spectacular views of Kautz Glacier and its canyon and of Basalt Cliff, a welded block-and-ash flow (see Fig. 30, p. 33).

43.3 Tatoosh granodiorite (Miocene) at Christine Falls.
70.0 In August of 2001, a series of debris flows roared
down Van Trump Creek and over the falls, frightening hikers and campers and triggering a media scare about a possible eruption and lahar from Mount Rainier. Geologists from the USGS Cascades Volcano Observatory flew over the creek to its source and found that the debris flows began when glacial meltwater, impounded at 9000 ft (2743 m) adjacent to the Kautz Glacier, overtopped a Little Ice Age lateral moraine and flowed into the Van Trump drainage basin (Vallance and others, 2003). Downcutting and lateral erosion by the meltwater caused failures of the saturated fragmental deposits along Van Trump Creek, which

then cascaded as boulder-rich debris flows more than 6000 ft (1830 m) to the Nisqually River. These slurries then continued for some distance along the Nisqually River, causing minor flooding. It was probably the record snowfalls of the mid-1990s that caused the water to pond by creating a thick kinematic wave of glacial ice that moved through Kautz Glacier. This thickening evidently formed a physical boundary at about 9000 ft (2743 m) that diverted the impounded meltwater along the glacier's left lateral moraine into the adjoining drainage of Van Trump Creek. Similar kinematic waves in response to very large snowfall years have been observed during Park Service surveys at other glaciers, including the Nisqually Glacier.

44.4 *71.0* Nisqually River bridge. Well-developed columns exposed on the valley wall of Rampart Ridge (see map on p. 61) to the west are part of a Quaternary Mount Rainier Andesite flow dated at 370 ka (Fig. A-19). (See "Lava and Ice", p. 30.) The Nisqually Glacier has been the subject of many observations, measurements, and investigations (Heliker and others, 1984) and is probably the most-studied glacier in the 48 conterminous states. The extent of the latest, or Little Ice Age advance of the Nisqually Glacier is clearly marked by a trimline of scoured bedrock and young trees and by lateral moraines that slope downvalley toward the terminal position reached by the glacier in about 1840 (see Fig. 26, p. 29). From its maximum recession position in about 1950, about 1.7 mi (2.7 km) upstream of the 1840 position, the glacier has re-advanced but shows no clear trend in motion. Excellent summaries of the research and of the activity and history of the glacier are found in Heliker and others (1984) and in Driedger (1986).

Historic debris flows—many probably related to glacial outbursts—and floods in this drainage have been discussed in papers by researchers such as Richardson (1968), Crandell (1971), and Hodge (1972). The present bridge was constructed after a 1955 outburst flood; the flow wave of that flood was augmented by landslides from the lateral moraine of the Nisqually Glacier. Remains of the pre-1955 bridge, a much lower structure, are slightly upstream.

44.6 *71.7* Tatoosh granodiorite is exposed on the right, slightly past (south of) the Nisqually River bridge.

45.2 *72.7* The road ascends along the west margin of a thick porphyritic andesite lava flow with local platy jointing (Fig. A-20).

45.6 *73.4* **OPTIONAL SIDE TRIP:** Ricksecker Point Scenic Loop. (This loop is about 1 mi [1.6 km] long and

photo by Beth Norman

Figure A-22. Pinnacle Peak in the Tatoosh Range as seen from the north. Most of the peak is composed of Tatoosh granodiorite; however, its top and lower western flanks are composed of the older Stevens Ridge rocks that the granodiorite intruded.

will add about that distance to the remaining mileages.) Turn right onto the scenic loop road at Ricksecker Point. This loop, which skirts the edge of deep glacial valleys, is well worth the trip for the visitor with a bit of extra time. This promontory is composed mostly of a thick Mount Rainier lava flow, mentioned at mile 45.2, whose steep and rubbly edges border the road between the Nis-

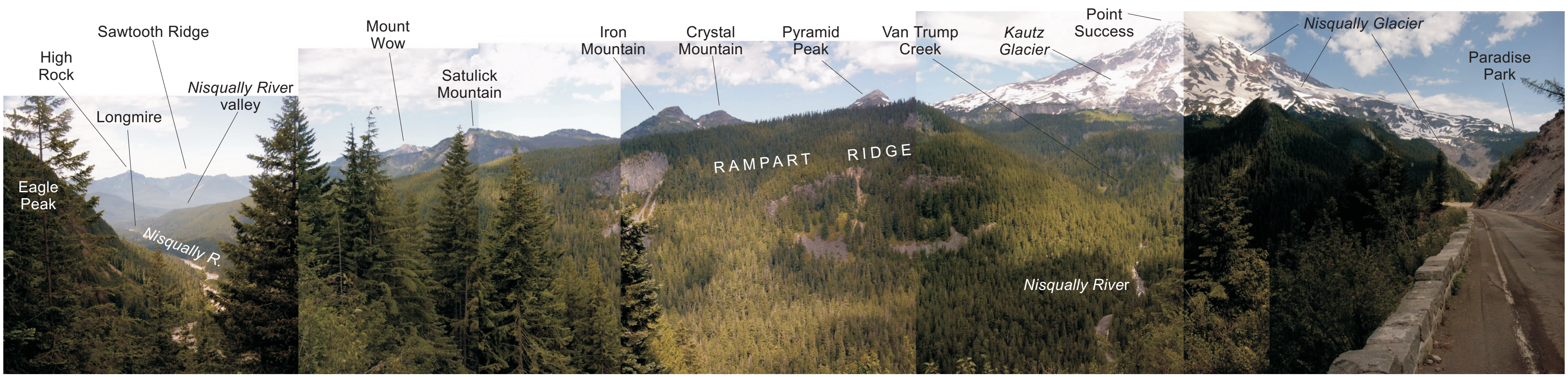


Figure A-21. A panoramic montage view with Paradise Park to the northeast, Mount Rainier to the north, and Eagle Peak in the Tatoosh Range to the southeast (extreme left). Photo taken from a viewpoint at the tip of Ricksecker Point, which sits on a ridge-forming stack of lavas that may be as young as 40 ka. The Nisqually River valley is in the foreground, and Rampart Ridge, which has been estimated to be about 300 ka by USGS geologist Tom Sisson, forms the opposite valley wall of the Nisqually River. Tertiary rocks that compose Mount Wow have been folded and make up the west limb of the north-northwest-trending Unicorn Peak syncline, whose axis trends almost directly away from the viewer in the left center of the photo. The rocks of Sawtooth Ridge and Mount Wow consist of the Ohanapecosh Formation (~36–28 Ma; Vance and others, 1987), whereas rocks of Iron and Crystal Mountains and Pyramid Peak are the younger Stevens Ridge Formation (~25 Ma; Paul Hammond, oral commun., 2006).

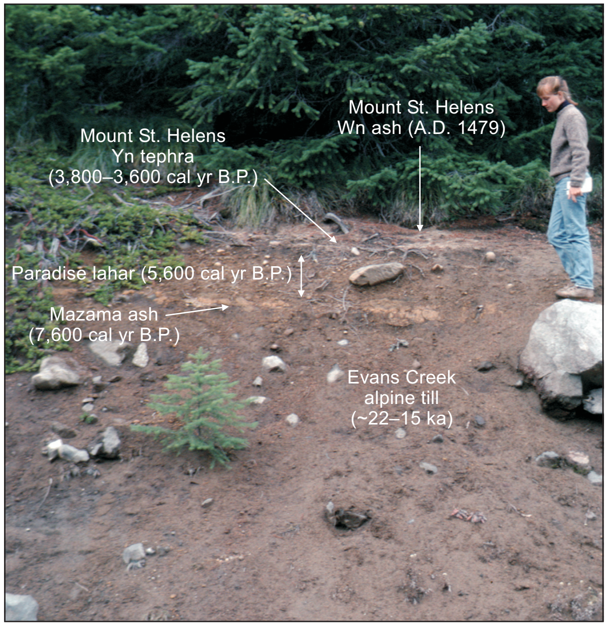


Figure A-23. Geologist Ruth Wilmoth examines the Paradise lahar deposit at Ricksecker Point. This layer is more than 800 ft (244 m) above the valley bottom! The 'exotic' ash layers that have been dated, such as those from Mount Mazama (Crater Lake) and Mount St. Helens, provide useful marker beds for assessing the relative ages of young geologic deposits. The boulders on the slope have weathered out of the Evans Creek till. Photo taken in 1992.

qually River bridge and the turnoff to Stevens Canyon Road. Geologist Tom Sisson has found that this is the youngest large lava flow at the volcano, with a radiometric age of about 40 ka.

The first turnout offers a clear view of Mount Rainier, the upper Nisqually River valley, and Nisqually Glacier. On a fine day, the second turnout will reveal a grand panorama from Mount Rainier to the folded Eocene volcanic rocks of Sawtooth Ridge to the southwest (Fig. A-21). The Unicorn Peak syncline in the pre–Mount Rainier rocks is visible to the northwest. At the second pullout (0.1 mi; 0.16 km) is an outcrop of blocky, flow-banded, light-gray andesite. This is the glassy edge of the Mount Rainier lava flow referred to above.

Continue about 0.9 mi (1.5 km) from the beginning of the loop and pull to the extreme right-

photo by Dave Norman

Figure A-24. The outcrop in Figure A-23 as it appears today. You can still see the large boulder and several other identifying features, but the ash layers are no longer visible. Lahar and ash deposits may be difficult to spot as they are easily eroded and covered.

hand side of the road into a pullout so that following traffic can pass safely. The central part of the Tatoosh Range looms to the south. The contact between the bedded rocks of the Stevens Ridge Formation to the west and the Tatoosh pluton to the east is located between Lane Peak and Pinnacle Peak (Fig. A-22). This is one of the unusual situations in which we see older rocks (Stevens Ridge) overlying the younger Tatoosh granodiorite, which was intruded into the Stevens Ridge rocks.

The lava flow and flow breccia exposed near this last turnout along the Ricksecker loop road are overlain by Evans Creek Drift (22–15 cal yr ka), by rubbly deposits of large glaciers that occupied the Nisqually and Paradise River valleys during the most recent ice age until about 15 ka, and by deposits of Holocene age—including the Paradise lahar and several ash layers (Figs. A-23 and A-24). The Paradise lahar deposit can be identified from the road as the approximately 1-m (3.3 ft)-thick layer that sits on a thin (2–10 cm; 0.8–4 in.) orange band of volcanic ash from Mount Mazama, also known as layer O (~6.7 ka; Hallet and others, 1997). Mount St. Helens tephra layers Yn and Wn are the most visible deposits that overlie the Paradise lahar near the top of this exposure.

photo by Beth Norman

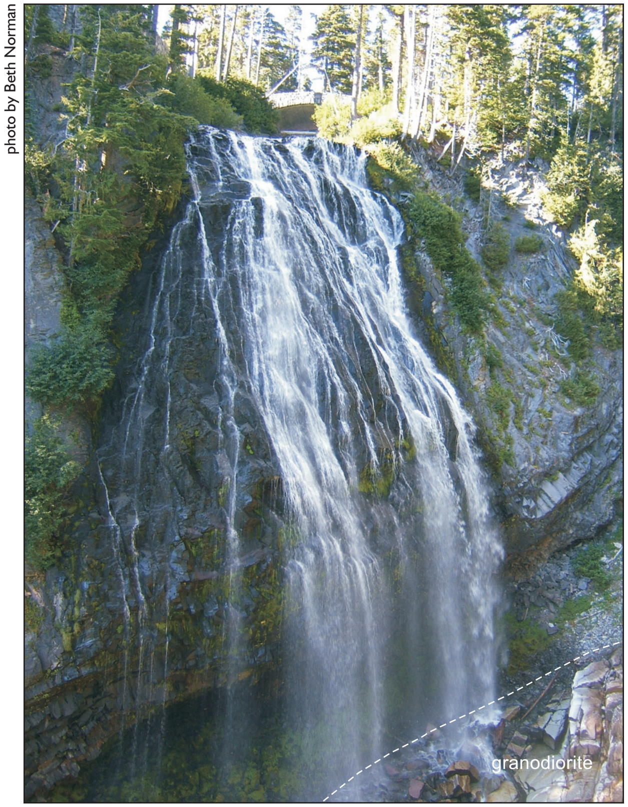


Figure A-25. Narada Falls. The contact between the lava flow and the underlying Tatoosh granodiorite is exposed at the falls.

Identified and described in detail by Crandell (1963a, 1971), the Paradise lahar is unusual because of its great flow thickness here and apparent rapid downstream attenuation. The deposit is about 270 m (800 ft) above the valley floor of the Paradise River at this location, indicating the lahar was at least that deep. Downstream the lahar was still more than 70 m (230 ft) thick, and its deposit is 1.2 m (4 ft) thick where it overlies layer O at Longmire. The low ratio of deposit thickness to flow depth, combined with the wide variation in clay content, suggest the Paradise lahar may have been catastrophically ejected. It must have come sloshing along the Paradise River valley much the same way a luge banks back and forth along its chute of ice.

Figure A-26. A trail in the alpine meadows at Paradise Park. Boulders and clayey yellowish-orange sediments exposed in trail cuts are deposits of the Paradise lahar (~5,600 cal yr B.P.). Nisqually Glacier is above the hiker and Cowlitz Glacier is to the upper right. Wilson Glacier behind the trees to the left is tributary to the Nisqually River. Kautz Glacier is in the upper left corner of the photo. View is to the north-northwest.

Crandell (1971) observed that the Paradise lahar generally is a very thin deposit and lacks constructional topography except at Reflection Lakes (Leg B) where hummocks are visible and the lakes occupy shallow depressions in the deposit. He bracketed the age of the Paradise lahar at about 6,600 to 6,000 yr B.P. because it overlies Mazama ash and appeared to underlie tephra layer D from Mount Rainier. However, Scott and others (1995) found wood at three locations near this site that ranged from 4,625 to 4,955 yr B.P., the youngest being at this Ricksecker Point outcrop. These radiocarbon ages indicate that the Paradise lahar is significantly younger than originally thought and might be related to the same episode of volcanism that produced the Osceola Mudflow (see Fig. 34, p. 37). Work by Vallance (USGS, written commun., 2003) suggests that the lahar underlying Reflection Lakes is older than the Paradise lahar.

Return to the main road and turn right to continue toward Paradise. Remember to compensate for the mileage along this side trip.

46.7 75.1 Crude columnar jointing is common in outcrops of Mount Rainier Andesite in north-side roadcuts along this stretch. Scattered exposures of brown-to-orange, poorly sorted, unstratified debris and orange and yellow boulders are remnants of the Paradise lahar.

47.4 76.3 Pullout with a good view of the Tatoosh Range to the southeast. Reddish beds of the Tertiary Stevens Ridge Formation volcaniclastic rocks are visible on Pinnacle Peak to the south.

47.7 76.7 Narada Falls Viewpoint (restrooms). A trail leads down to viewpoints of the waterfall as it flows over lava columns (Fig. A-25). The contact between the lava flow and the underlying Tatoosh granodiorite is exposed at the falls.

Figure A-28. Glacial grooves, striations, and fractures in Mount Rainier Andesite near Panorama Point are telltale evidence of the work of past glaciers. The sculpting is accomplished by 'tools' (rocks) incorporated by the ice that move with it. The glacier moved from lower right to upper left. Marker pen for scale (5.25 in. or 13 cm).

48.4 77.9 Turnoff to Stevens Canyon and Ohanapecosh (Leg B); continue straight ahead toward Paradise. Tatoosh granodiorite with inclusions is exposed on the right.

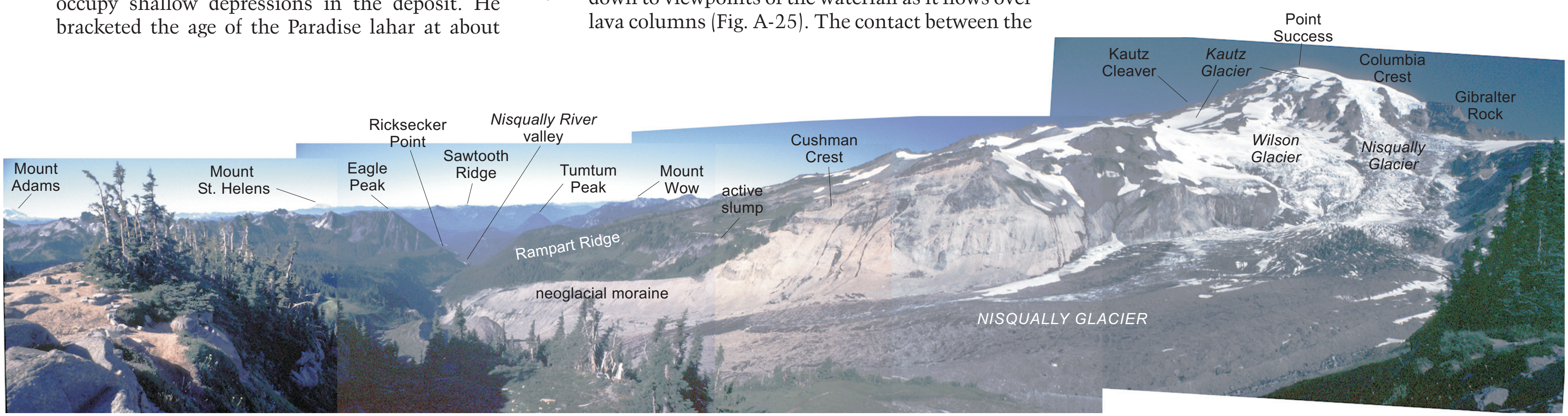


Figure A-27. A panorama from Glacier Vista in the meadows at Paradise Park. Mount Rainier is on the right (north) and Mount Adams is on the extreme left (south-southeast). This vista shows the rewards of making the hike (1100 ft or 300 m elevation gain) from the Paradise area.

49.4 *79.0* Pullout on the left, offering a good view of Mount Rainier to the north and the glacially serrated peaks of the Tatoosh Range to the south. An outcrop of the Paradise lahar deposit contains a large block of andesite.

50.3 *80196* Paradise area. Pull into the parking lot of the Henry M. Jackson Memorial Visitor Center. Numerous large boulders in the Paradise lahar deposit lie on the ground surface in this area. The lahar deposit and various tephra layers are visible in exposures at the parking area and along the trails that weave through the alpine meadows (Fig. A-26). A map of trails is available at the information desk. A hike to Glacier Vista (3.7 mi [6 km] round trip; elev. gain about 1000 ft [300 m]) will allow the visitor to observe the Nisqually Glacier, neoglacial moraines, and Mount Rainier lava flows, breccias, and block-and-ash deposits (Fig. A-27). A shorter hike along an asphalt trail to Nisqually Vista provides an excellent view of the glacier's terminus. The more energetic hiker can venture farther up to Panorama Point for additional views of the Nisqually and Wilson Glaciers, the layers exposed in uppermost Rampart Ridge, and glacial striations (Fig. A-28). The Moraine Trail, accessible via the Dead Horse Creek Trail, is a 3-mi (4.8 km) round trip that accesses spectacular views of the glacier. The trail ends at the left lateral moraine that was created during the Little Ice Age and offers a close-up view of the terminal area of the Nisqually Glacier.

Figure A-29. An historic photo of Paradise ice caves. These caves no longer exist because Paradise Glacier has receded past this location. National Park Service photo taken by Ranger Potts in 1953.

The ice caves in this area, once a favorite destination of glacier aficionados, are no longer safe and have been closed (Fig. A-29).

You can start Leg B at the north end of the Paradise parking area and continue that leg by turning left onto Stevens Canyon Road after about 2.3 mi (3.7 km), or you can return to the Nisqually Entrance to Mount Rainier National Park by turning right.

Remember to reset your odometer when you start another leg. ■