LEG H: ACROSS THE CASCADES AT WHITE PASS

Ohanapecosh (State Route 123) to Naches via U.S. Highway 12

by Patrick T. Pringle, Paul E. Hammond, Newell P. Campbell, and Wendy J. Gerstel*

This 46-mi (75 km) leg is the eastern segment of the White Pass Scenic Byway and was featured in Newell Campbell's geologic road guide (1975) (Fig. H-1). The byway passes through one of the most scenic and geologically interesting areas in Washington. There are tens of volcanic centers that range in age from earliest Miocene to Pleistocene. Late Paleozoic/Mesozoic sedimentary rocks and metamorphic rocks, glacial deposits, and large active landslides are also exposed along the way. Begin the journey by ascending from the valley of the Cowlitz River (elev. ~1580 ft or 480 m) through the valley of its tributary, the Clear Fork Cowlitz River, toward White Pass (elev. 4470 ft or 1363 m). En route you will pass west-dipping Ohanapecosh Formation beds (about 36 to 28 Ma, or late Eocene to middle Oligocene age [Vance and others, 1987]) and cross a major fault boundary along the western margin of the Rimrock Lake inlier. The Rimrock Lake inlier is a body of older rocks that pokes up through younger rocks. East of White Pass, you will thread your way through andesitic lavas from Ice Age volcanoes that erupted both north and south of the highway and drive past more outcrops of the pre-Tertiary Rimrock Lake inlier rocks before passing into a section of younger rocks near Tieton Dam. Before arriving at the junction of U.S. Highway (US) 12 with State Route (SR)

* See "Contributors", p. ii, for affiliation.

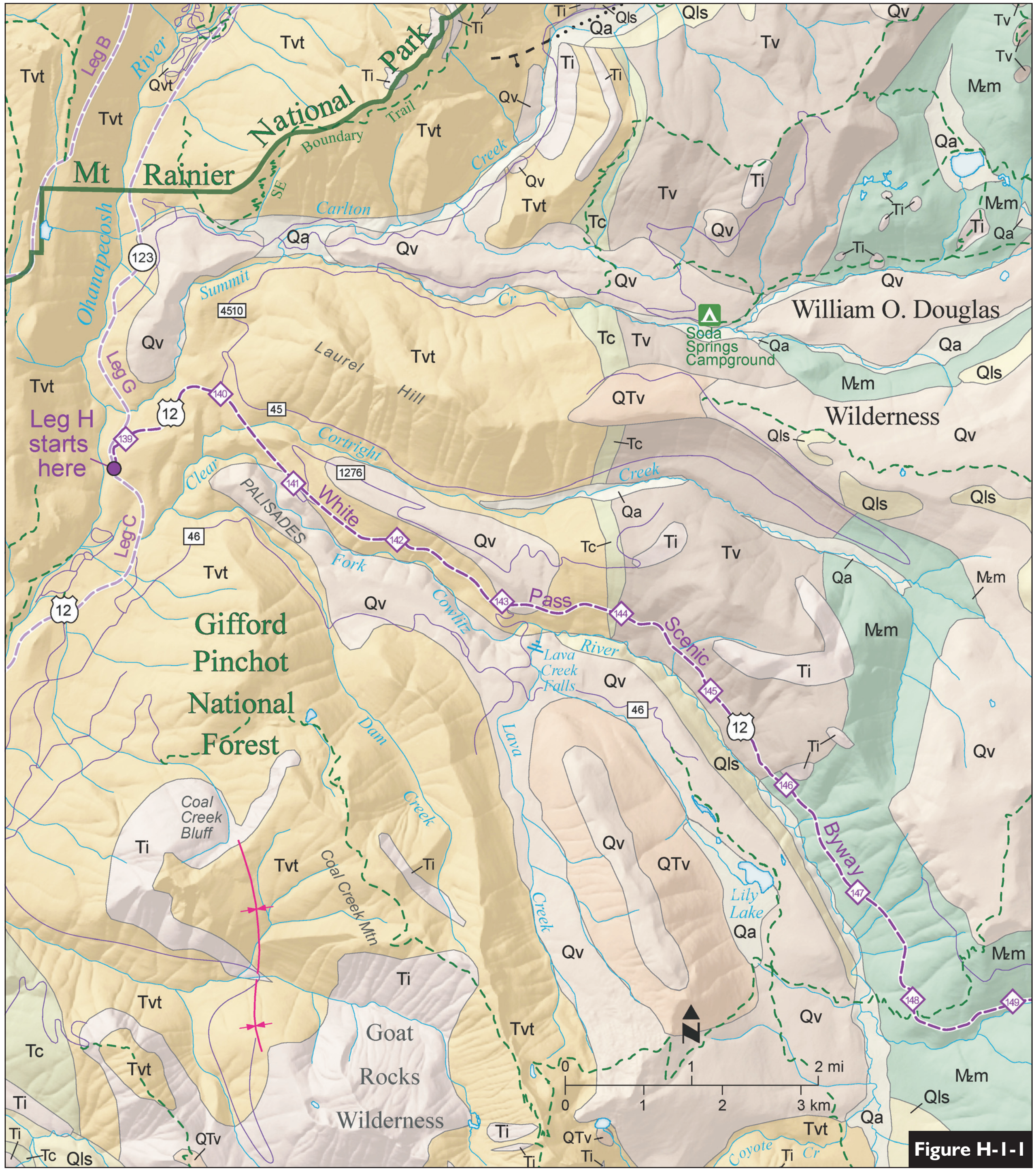

Figure H-1. Geologic map for Leg H (five consecutive panels). The geology was adapted from 1:100,000- and 1:500,000-scale digital versions of Schasse (1987b), Walsh (1986b), and Schuster (2005) and has been draped over a shaded relief image generated from 10-m elevation data. The leg maps were constructed 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.

Figure H-2. A 6.5-ft (2 m) sill (between arrows) in southwest-dipping beds of Ohanapecosh Formation rocks along the north side of US 12. The beds about 3 ft (1 m) above the sill are gently folded. View is to the northwest.

410 (elev. 1608 ft or 490 m) at the end of Leg H, you will pass some textbook-quality displays of columnar jointing in lava flows and examine a complicated interplay of volcanic deposits and flows buried by younger lavas of one of the world's largest lava flow complexes, the Grande Ronde Basalt. At other locations, invasive flows that entered stream sediments are exposed, and in places river valleys have been displaced or buried by lavas. The distinctive vegetation zones traversed en route have evolved and adapted to both climate and geology.

The highway is sometimes closed in winter, so it is wise to check on road conditions before traveling. Road status can be checked at Washington State Dept. of Transportation via their website or by phone. (See "Websites and Phone Numbers", p. 176.)

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* Junction of SR 123 and US 12. Sills and pyroclastic flows in Ohanapecosh rocks are visible here. Fiske and others (1963) measured a stratigraphic section of the Ohanapecosh Formation volcaniclastic rocks from Stevens Canyon to the Ohanapecosh River and then to the east along US 12 at 6000 ft (1829 m) thick.

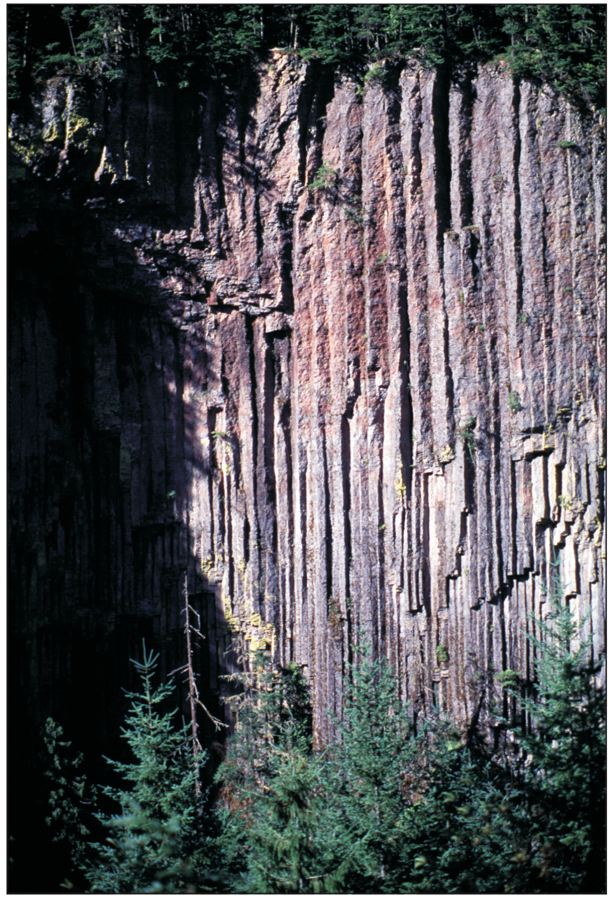

Figure H-3. Towering columns in the hornblende dacite flow on the south side of the Clear Fork Cowlitz River. The columns are about 650 ft (200 m) in height. Geologist Geoff Clayton (1983) obtained a radiometric age of about 0.65 Ma on this lava flow. View is to the south-southwest from the Palisades viewpoint.

0.3 *0.5* Milepost (MP) 139.

0.6 *1.0* A poorly sorted deposit or diamicton here is till of Evans Creek age, 22 to 15 cal yr B.P. Evans Creek is the youngest major episode of alpine glaciation in this area.

photo by Beth Norman

Figure H-4. Outcrop of hydrothermally altered volcaniclastic rocks of the Ohanapecosh Formation north of US 12 near MP 143.

1.2 *1.9* Near MP 140, Forest Roads (FRs) 45 and 4510 lead to Soda Springs Campground. The historic Cowlitz Trail heads at the campground. This route linked local tribes east and west of the Cascade crest, a distance of more than 40 mi (64 km) between settlements. Outcrops of Ohanapecosh Formation volcaniclastics are visible before and after FR 45.

1.9 *3.0* Ohanapecosh sedimentary rocks dip about 30 degrees to the southwest several hundred yards (meters) west of MP 141 (Fig. H-2). The sill is a plagioclase-phyric olivine basalt. Note the gentle 10- to 13-ft (3–4-m) wavelength folds in the rocks above the sill. The deformation likely occurred during emplacement of the sill.

2.3 *3.7* Palisades rest area. Here are some spectacular columns in the Clear Fork Dacite, an intracanyon lava flow of Pleistocene age from a vent near Goat Rocks (Fig. H-3). Clayton (1983) dated the Clear Fork flow at 0.65 Ma.

Why are the columns here wider at the top? The columns develop at different rates as cooling progresses both upward from the base and downward from the top (see Fig. F-14, p. 110). The flow-top rubble at this site has been removed by subsequent glaciation. Hammond has suggested that

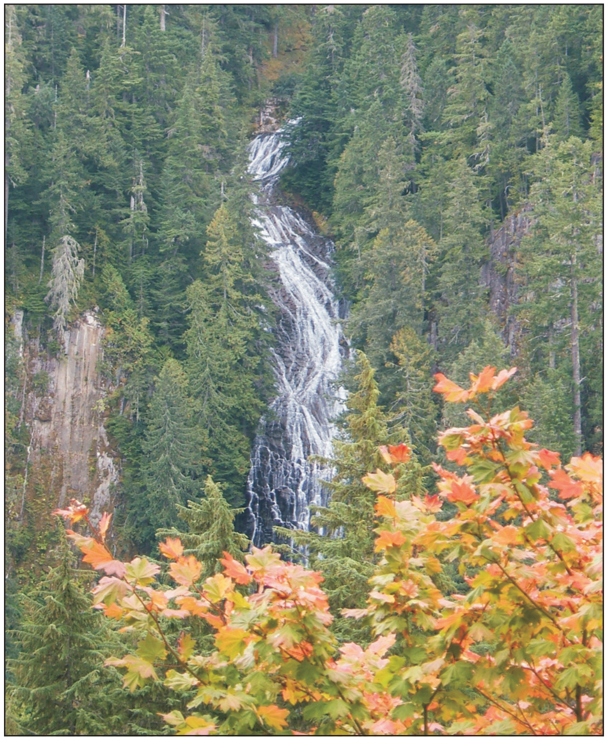

photo by Dave Norman

Figure H-5. Lava Creek falls. The wispy nature of the falls is due to the water flowing over and around Palisades columns, some of which are visible on the left.

this same flow may have been ponded by ice in the Cowlitz River valley to the west.

2.5 *4.0* FR 1276.

3.0 *4.8* West-dipping water-laid beds of the Ohanapecosh Formation crop out here.

4.1 *6.6* The sedimentary rocks here dip at least 10 degrees more steeply to the southwest than the rocks 2 mi (3 km) to the west. The beds become steeper over the next several miles and are nearly vertical as you approach the rocks of the pre-Tertiary Rimrock Lake inlier (unit Mzm).

4.2 *6.7* MP 143. Outcrop of hydrothermally altered volcaniclastic rocks of the Ohanapecosh Formation (Fig. H-4). A small amount of coal is exposed at the east end of the outcrop. Also visible in the outcrop is a vesicular olivine basalt flow of Hogback Mountain (Fig. H-1-2) and a flow breccia. This outcrop is continuous to mile 4.5.

4.5 *7.2* Columnar Hogback Mountain olivine basalt is exposed on the north side of the highway. This lava flow originated at Hogback Mountain about 8 mi (12.9 km) to the southeast. Clayton (1983) estimated (by whole-rock K-Ar dating) the age of a lava flow near the top of the Hogback Mountain volcano at about 1.53 Ma; using geomagnetic polarity reversals, he dated the lower part of the volcano at between 2.47 and 3.40 Ma. (See the "Paleomagnetism" sidebar on p. 104.)

4.6 *7.4* The pullout to the right offers an excellent view of Lava Creek falls as the stream goes over the Palisades columns and plunges into the Clear Fork Cowlitz River (Fig. H-5). The river incised its course along the contact between the valley dacite flow and the older Ohanapecosh Formation. Lava Creek was not able to erode the valley dacite flow at the same rate as the river, and as a result the waterfall was formed.

4.7 *7.5* The contact between the Ohanapecosh Formation and the overlying Hogback Mountain basalt flow.

4.8 *7.7* The Ohanapecosh Formation is exposed for about 0.8 mi (1.2 km). Higher up, in cliffs above the roadway, Hogback Mountain basalt can be seen.

5.2 *8.3* MP 144.

5.5 *8.8* Intrusive rocks are exposed on the left near where the road curves to the right (if eastbound). At the turnout slightly past this curve, note the valley slightly east of the high exposure of intrusive rocks, as well as the yellowish alteration in volcanic rocks adjacent to the intrusive body. The intrusion evidently altered and weakened the surrounding rocks.

6.0 *9.7* This stretch of the road passes through colluvium as you approach the margin of the pre-Tertiary rocks.

7.0 *11.2* The inferred fault contact between the Russell Ranch Formation and Ohanapecosh Formation is near here. Although the fault itself is not visible, the east block is up relative to the west block, which places black carbonaceous shale of the Russell Ranch (east) against light-colored andesites of the Ohanapecosh on the west. This faulting causes chronic landslide problems here (Fig. H-6).

photo by Beth Norman

Figure H-6. Roadwork along an unstable slope where altered volcanic rocks adjacent to an intrusion (right) frequently collapse onto the highway. This outcrop is slightly east of MP 144 on the north side of the highway.

7.1 *11.4* MP 146 area. Hammond (1980) described the steeply west-dipping beds of Summit Creek sandstone here that overlie shattered and sheared argillite rocks of the Russell Ranch Formation. The Summit Creek deposits are arkosic sandstone that underlie the Ohanapecosh Formation in this part of the Cascade Range and thus predate the onset of Cascade volcanism. The Summit Creek rocks are older than the 36 Ma fission-track age on overlying volcanic rocks and younger than the 55- to 44-Ma fission-track ages for the unnamed volcanic rocks below the sandstones (Vance and others, 1987). There are some intrusions exposed here in the Russell Ranch Formation that also cut, and thus are younger than, the rocks of Summit Creek.

The Russell Ranch Formation mostly consists of sheared, fine-grained oceanic sedimentary rocks that were buried and weakly metamorphosed; the rocks include argillite and arkosic sandstone along with tuffs and radiolarian cherts. The argillite is highly shattered in this area, and Hammond and others (1994) interpreted this shearing as a result of faulting along the west margin of the pre-Tertiary Rimrock Lake inlier.

photo by Dave Norman

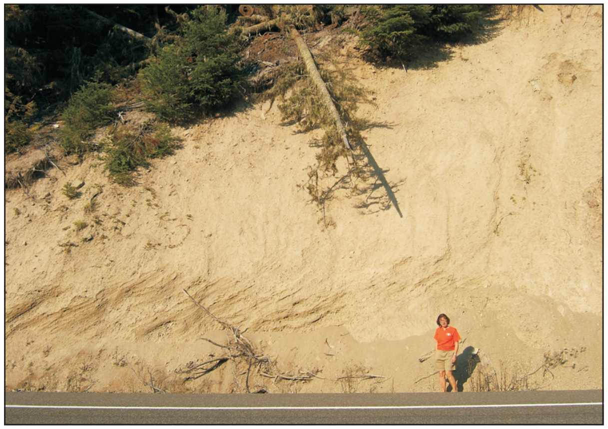

Figure H-7. The pre-Tertiary Russell Ranch Formation (to the right of geologist Beth Norman) near MP 148. The crude high-angle layering to the left is part of a talus cone exposed by road excavation.

8.1 *13.0* Intrusive andesite with large hornblende and biotite crystals crops out here.

8.2 *13.2* The first good outcrops of the Russell Ranch Formation.

8.9 *14.3* The pullout to the right has a good exposure of the Russell Ranch Formation (Fig. H-7).

9.1 *14.6* Scenic vista points near here (MP 148) offer views of Goat Rocks to the south-southwest (Fig. H-8), Mount Rainier to the northwest (Fig. H-9), and the shattered Russell Ranch Formation across the road to the north (Fig. H-10). The Clear Fork Dacite flow is visible to the west.

9.6 *15.4* Russell Ranch Formation is exposed for next 0.4 mi (0.6 km).

10.6 *17.1* Note the hummocky landslide surface in the forest south of the road between here and Knuppenburg Lake.

10.7 *17.2* Knuppenburg Lake to the right is dammed by the rockslide–debris avalanche that originated from the north flank of Hogback Ridge, due south of the lake. Radiocarbon ages for the submerged subfossil forest in the lake will reveal the approximate age of the landslide (Fig. H-11). A few hundred yards (meters) upstream of the lake, debris-flow deposits of the last few decades have partially buried the trees growing adjacent to Millridge Creek.

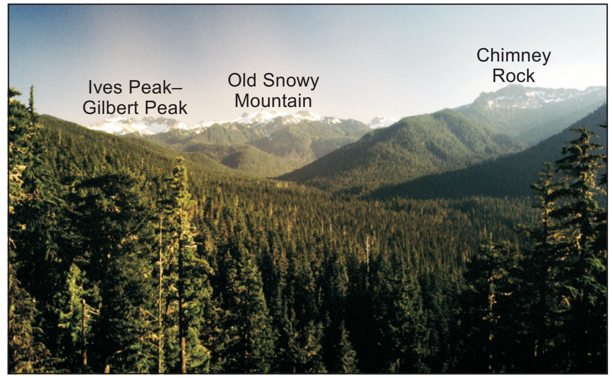

Figure H-8. Goat Rocks Wilderness. The mountains are erosional remnants of Goat Rocks volcano of Pliocene to Pleistocene age. View is to the south-southwest up the Clear Fork Cowlitz River.

Figure H-10. Shattered rock of the pre-Tertiary Russell Ranch Formation is exposed near MP 148 along US 12. The Russell Ranch unit includes marine sedimentary and volcanic rocks that are at least in part of Late Jurassic and Early Cretaceous age (~145–130 Ma). The complex consists mainly of sandstones and mudstones with minor conglomerates, reworked water-lain tuffs derived from volcanic-arc volcanoes, and pillow lavas (altered to greenstones) that likely formed at an oceanic ridge (Miller, 1989).

Hogback Ridge is the source of the Hogback Mountain olivine basalt, which overlies shattered and landslide-prone clastic rocks of the Russell Ranch Formation. According to Swanson and Clayton (1983), the late Pliocene and early Pleisto-

Figure H-9. Mount Rainier from near MP 148 along US 12. The snow-covered Tatoosh Range is low on the horizon to the south (left) of Mount Rainier. The tooth-like rock to the right of Mount Rainier's summit cone is Little Tahoma Peak, an erosional remnant of Mount Rainier. View is to the northwest.

Figure H-11. Ghostly subfossil trees in Knuppenburg Lake were drowned when a landslide from Hogback Ridge blocked the valley. The small delta of Millridge Creek is visible in the upper left corner of the photo. Radiocarbon dating of the trees will provide an approximate age for the event, which may have been triggered by an earthquake. View is to the southeast.

cene Hogback Mountain shield volcano was 3 mi (5 km) wide and 2300 ft (700 m) high. Some of its more than 200 lava flows, which are intercalated

Figure H-12. Tumac Mountain tephra cinder cone. Geologist Geoff Clayton (RH_2 Engineering Inc.), who conducted detailed studies in this area, noted that a crater is hidden in the trees on the west flank of the cone. He estimated the age of the Tumac Mountain volcano at 20 to 30 ka. View is to the southeast. Photo from Clayton, 1983.

with those of the Pliocene to Pleistocene Goat Rocks volcano, poured as far as 18 mi (30 km) down valleys. Clayton (1983) suggested that, during its youth, Hogback Mountain volcano might have looked similar to the Tumac Mountain complex. Tumac Mountain (Fig. H-12) is a late Pleistocene basaltic volcano located 1.8 mi (3 km) north of Spiral Butte. Clayton estimated its age to be 30 to 20 ka.

11.0 17.7 Leech Lake on the north. Here is another outcrop of shattered Russell Ranch Formation rocks.

11.6 18.7 FR 1284 and entrance to a Department of Transportation maintenance facility.

12.3 19.8 White Pass, elevation 4470 ft (1363 m). Andesite crops out on the north side of road, and the Russell Ranch Formation is exposed on the south side. Spiral Butte is ahead to the northeast (Fig. H-13).

12.7 20.4 Boundary between Gifford Pinchot (west) and Wenatchee (east) National Forests.

12.9 20.7 The Pacific Crest Trail crosses the route here.

13.2 21.2 This roadcut is in Spiral Butte dacite (Fig. H-14).

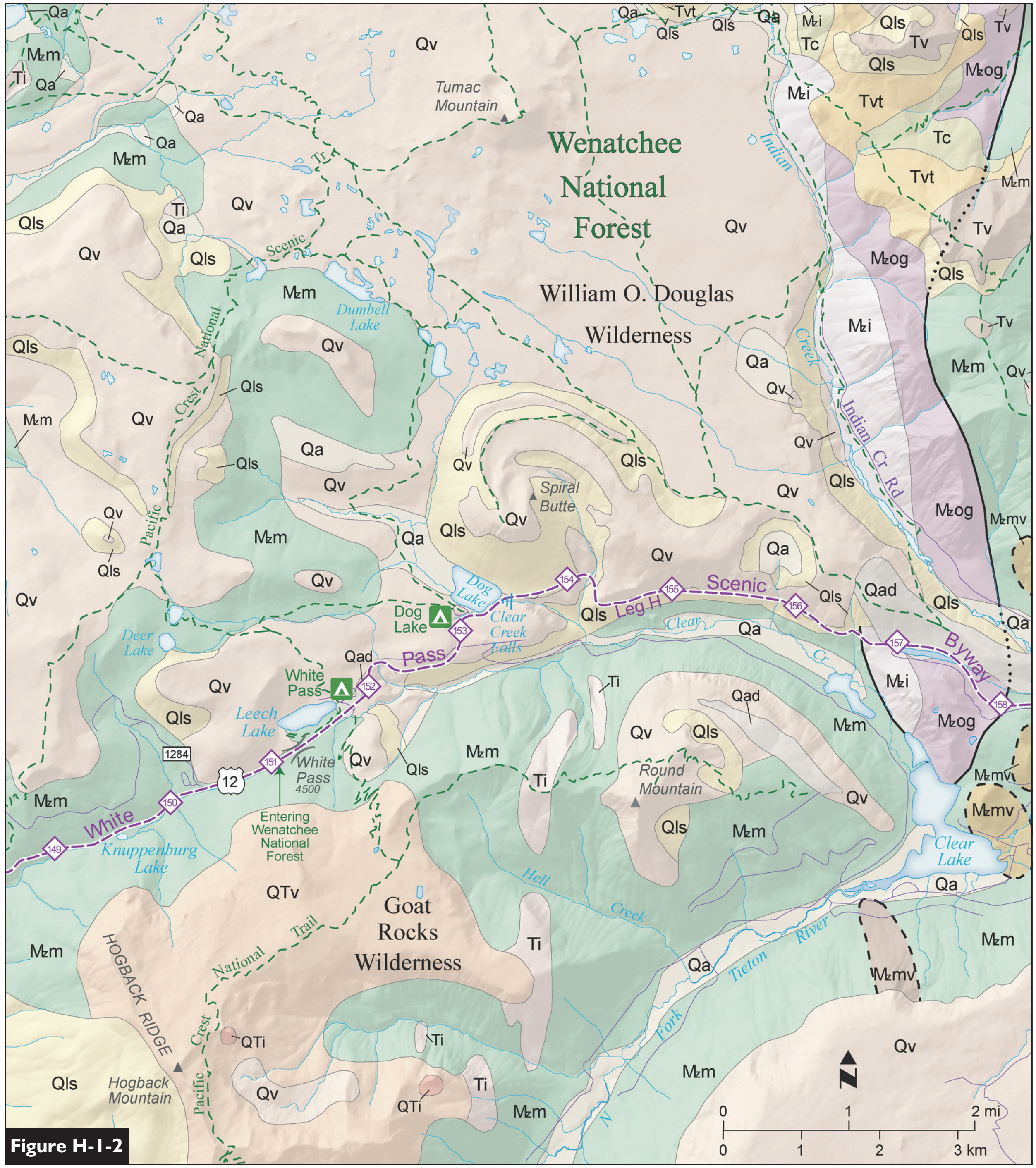

Figure H-1-2

photo by Beth Norman

Figure H-13. Spiral Butte is a Pleistocene dacite lava dome.

photo by Beth Norman

Figure H-14. Platy jointing in Spiral Butte dacite along the north side of US 12 near MP 152.

13.7 *22.0* Spiral Butte lavas. Spiral Butte is a dacite dome of Pleistocene age (Fig. H-15). Clayton (1983) inferred that during the most recent Ice Age advance of alpine glaciers (~22–15 ka), Spiral Butte may have partially dammed the ice that moved south from the Tumac Mountain plateau. This obstacle would have concentrated the flow of ice in the Clear Creek valley. Erosion by the ice would have exposed the fragmental deposits at the summit of Spiral Butte and created the cliffs that have now raveled to form the talus slopes seen northeast of Dog Lake. Alternatively, an earlier thick ice cap

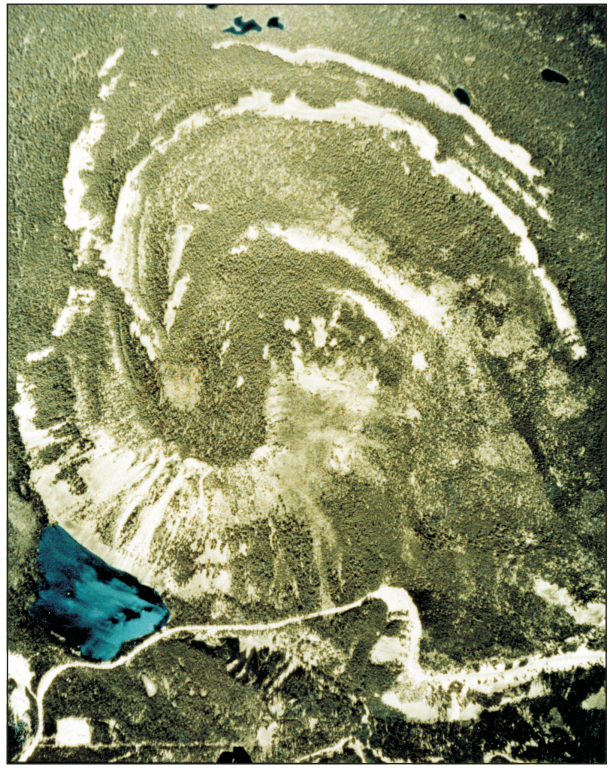

Figure H-15. Aerial view of the Spiral Butte dacite dome. The sparsely vegetated spiral arms at the top are talus-draped margins of a lava flow levee. The lava flowed north and then spiraled clockwise along the eastern side of the volcano, possibly channeled by ice. According to geologist Geoffrey Clayton, Dog Lake (lower left) is dammed between a hornblende-andesite lava flow from an unnamed peak near Deer Lake to the west and rocks of Spiral Butte. Spiral Butte dome is about 2 km (1.2 mi) in diameter. North is to the top. Photo from Clayton (1983).

centered on the Tumac Mountain plateau could have diverted the thick lava flow of Spiral Butte to the southeast into the Clear Creek valley. There the lava may have cooled against ice, as Lescinsky and Sisson (1998) have suggested for flows at Mount Rainier (see Fig. 27, p. 30). Tom Sisson and Marvin Lanphere (USGS, written commun., 2004) reported an $^{40}Ar/^{39}Ar$ age of about 102 ka for Spiral Butte lava.

14.4 *23.1* Dog Lake North Campground.

photo by Beth Norman

Figure H-16. Clear Creek falls. A silicic andesite lava flow forms the falls. A short trail affording views of the falls begins at the pullout at mile 14.8.

14.8 *23.8* The turnout on the south side of the road has a scenic view of Clear Creek falls (Fig. H-16), a view down Clear Creek valley to the southeast, and restrooms (except in winter). Clayton (1983) mapped the silicic andesite lava flow that forms the falls. It was erupted from a vent area about 3 mi (5 km) farther west. The flow overlies a basalt flow that Clayton dated at 0.65 Ma.

15.7 *25.2* A broad turnout on the south side of US 12 at a pronounced curve about 0.5 mi (0.8 km) past MP 154 offers a panoramic view of the local terrain (Fig. H-17): Round Mountain to the south-southeast and the Clear Creek valley and Rimrock Lake to the east. *Note:* this turnout may be inaccessible owing to rockfall hazards.

16.0 *25.7* Platy andesite crops out for the next 1.5 mi (2.4 km).

16.3 *26.2* MP 155.

17.6 *28.3* At this curve on the left, the contact between Indian Creek Gneiss (to the east), about 154 Ma, and the sheared rocks of the Russell Ranch Formation (>144–146 Ma) is exposed (Clayton, 1983; Miller, 1989). Till deposits of alpine glaciers are extensive in this area.

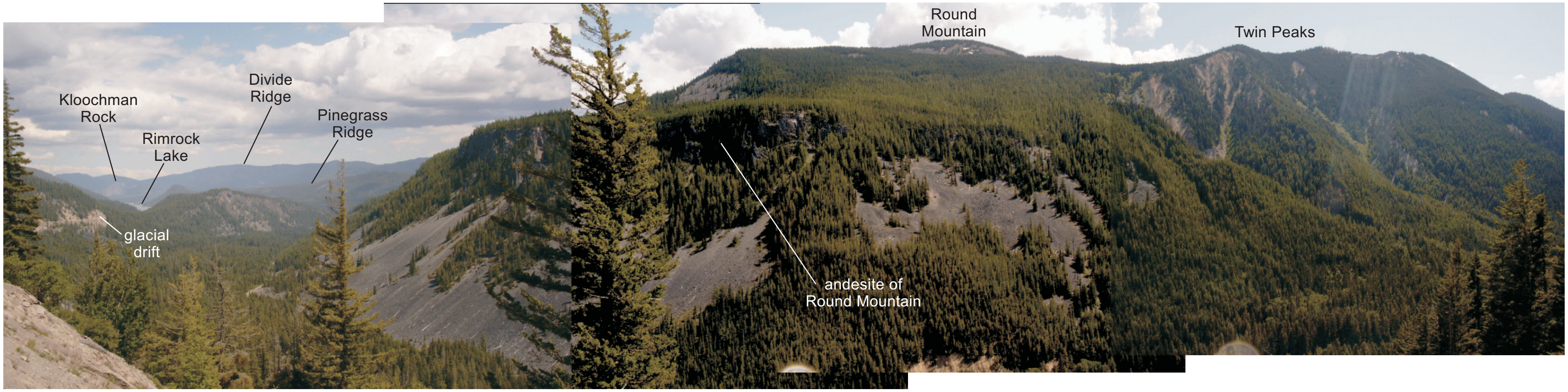

Figure H-17. Panoramic view across the valley of Clear Creek from a turnout near MP 154 on US 12. The view spans the distance from Divide Ridge (on the skyline to the east southeast) to Twin Peaks (south-southwest). Twin Peaks is composed largely of the Russell Ranch Formation with a spine of Tertiary dacite, whereas Round Mountain produced an andesite flow dated by Clayton (1983) at 0.8 Ma. Pinegrass Ridge is underlain by the Tieton Andesite flow (~1.64 Ma) from Goat Rocks volcano (12 mi [19 km] to the southwest of this viewpoint) and several other Pleistocene lava flows. Divide Ridge exposes more than 1700 ft (518 m) of the Grande Ronde Basalt and interbeds. Swanson (1967, 1978) noted that the upper part of this sequence at the west end of Divide Ridge is at an elevation of 6888 ft (2100 m), whereas undeformed coeval flows near the northern and eastern part of the Columbia Basin are at about 2394 ft (730 m). Assuming the latter areas represent a stable datum, Divide Ridge may demonstrate 4429 ft (1350 m) of absolute uplift (Swanson and others, 1989). Hogback Mountain is just out of the photo to the right. View is to the southeast.

17.9 *28.8* Indian Creek Gneiss with amphibolite crops out in this roadcut (Fig. H-18). The rocks are highly sheared and deformed by high-temperature metamorphism. Pegmatite dikes intrude the outcrop.

18.9 *30.4* An outcrop of greenstone of the Russell Ranch Formation is on the south side of road slightly west of MP 158.

19.3 *31.0* More greenstone of the Russell Ranch Formation.

19.9 *32.0* Tieton Road–Clear Lake area turnoff.

20.1 *32.3* Campbell (1975) noted that a small outcrop on the north side of the highway here is the terminus of the olivine basalt flow from the Tumac Mountain cone, about 6 mi (10 km) to the northwest. While some earlier researchers thought that the youthful-looking Tumac cinder cone was Holocene in age, Clayton (1983) carefully studied the evidence for glaciation at Tumac Mountain and concluded the volcano predated the most recent episode of major alpine glaciation of about 22 to 15 ka.

20.3 *32.7* Indian Creek. MP 159. The type locality of the Indian Creek Gneiss, one of the units in the Indian Creek complex, lies about 4 mi (6.5 km) to the northwest. Those who want to further explore the rocks of the Indian Creek complex via foot trails and nearby roads can find information in Miller (1985) and Northwest Geological Society (1991).

20.7 *33.3* Indian Creek Campground.

20.9 *33.6* Silver Beach resort.

21.7 *34.9* Heritage Marker for the Russell Ranch that was flooded by the reservoir.

22.3 *35.9* Steeply dipping beds of the Russell Ranch Formation are exposed north of the highway.

22.7 *36.5* Rest area south of road (not marked). Chert beds north of the highway.

23.2 *37.3* MP 162. Sheared sedimentary rocks north of the highway include turbidites of siltstone, sandstone. and shale (Fig. H-19). Faulted greenstone and cherts are below the turbidites. Radiolarian cherts in the Russell Ranch Formation were found near here by Miller and others (1993). They noted that the radiolarians in the cherts are compatible with a Late Jurassic to Early Cretaceous age. For the next 1.5 mi (2.4 km), you are in sheared metasedimentary rocks and basalts of the Russell Ranch Formation.

Figure H-18. Indian Creek Gneiss and amphibolite crop out north of the highway in this roadcut between MPs 157 and 158.

Figure H-1-3

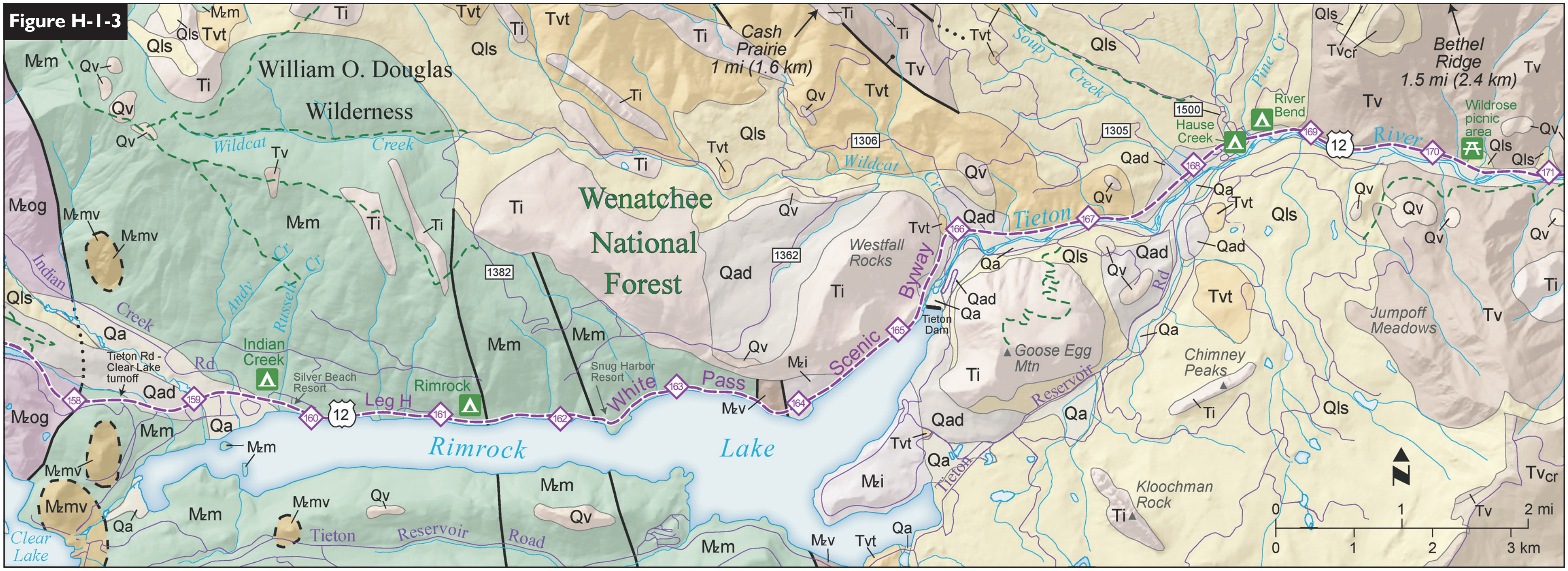

Figure H-19. Sheared sedimentary rocks north of the highway near MP 162 include turbidites of siltstone, sandstone, and shale. Faulted greenstone and cherts are below the turbidites.

23.3 *37.5* An outcrop of sheared shale and greenstone with slickensides is north of the highway. The greenstones include remnants of pillow basalts.

23.7 *38.1* Snug Harbor resort.

25.0 *40.2* The sheared intrusive rock exposed along the highway here is mapped as the "trondhjemite" of the Indian Creek pluton of Jurassic age (Swanson and others, 1989). The name for this type of low-potassium granitoid rock originated at Trondhjem, Norway.

25.3 *40.7* Rounded boulders of probable glacial till can be seen north of the road at MP 164. Note the slickensides in an area of sheared intrusive rocks near here.

26.3 *42.3* MP 165. Swanson and others (1989) pointed out that there is a dark margin of hornfelsed Oligocene Wildcat Creek lapilli tuff in contact with the Pliocene/Oligocene Westfall Rocks here. They described the Westfall Rocks as a 'micro' diorite because of its small crystals. The heat of the Westfall Rocks intrusion along this contact has largely recrystallized the tuff along the dark margin.

26.6 *42.8* Exit Tunnel. Tieton Dam was constructed between the masses of shallow intrusive diorite at Goose Egg Mountain (east) and Westfall Rocks

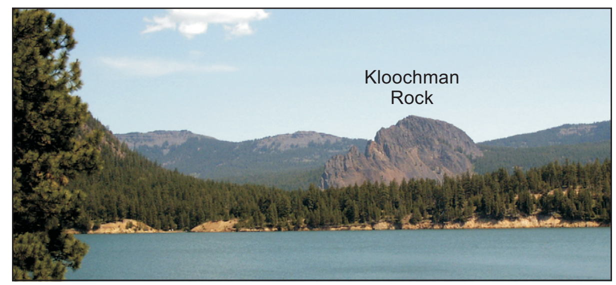

Figure H-20. A view southeast from US 12 near the east end of Rimrock Lake shows the extreme south end of Goose Egg Mountain (far left) and Kloochman Rock with Divide Ridge, composed of many flows of Grande Ronde Basalt, in the background. The area of low relief behind Kloochman Rock largely consists of large, deep-seated landslides from Divide Ridge. Yellowish forested exposures on the opposite lake shore are Quaternary glacial drift overlying rocks of Jurassic Indian Creek complex.

(west)(Fig. H-20) that Hammond has dated at 25.7 and 26.1 Ma respectively using Ar-Ar dating. The dam was built between 1917 and 1925, chiefly for irrigation purposes. In the next 0.1 mi (0.1 km),

Figure H-21. Wildcat Creek sedimentary rocks on the north side of US 12 near MP 167. These Oligocene rocks, which contain laharic deposits (between the white arrows), could be correlative with the Ohanapecosh Formation. This exposure is about 20 ft (6 m) in height.

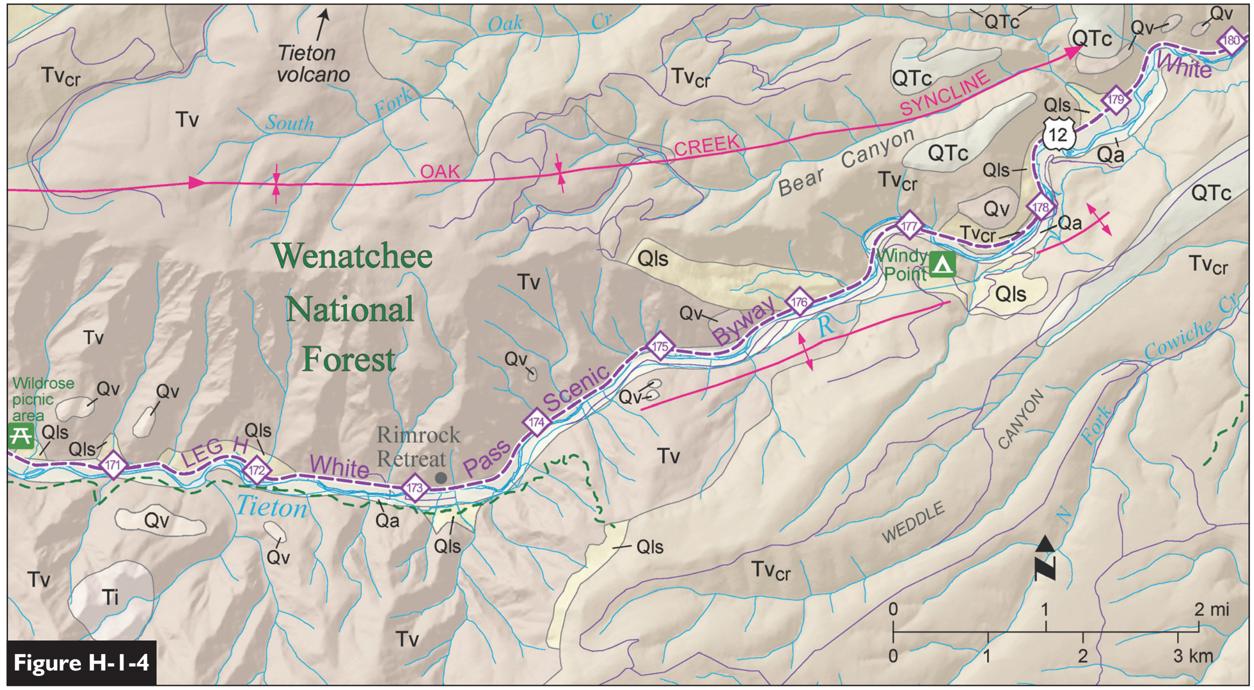

Figure H-1-4

there are exposures of the Westfall Rocks diorite. Straight ahead in the distance are Pleistocene lava flows of olivine basalt. These flows originated from a vent to the northwest and moved down Wildcat Creek (Campbell, 1975). Hammond notes Ar-Ar dates of 1.38 and 1.31 Ma on the flows.

27.2 *43.8* Rimrock Grocery store on the right. Gabbroic rock crops out on the left side of road, then you cross Wildcat Creek (Fig. H-1-3).

27.3 *43.9* MP 166.

27.4 *44.0* Wildcat Creek Road and FR 1306 are on the left.

28.0 *45.0* The light greenish, mostly fine-grained volcanic sedimentary beds that crop out north of the road near here are the Wildcat Creek tuffs. Vance and others (1987) obtained dates on these rocks that range from about 34 to 30 Ma. Hammond (2005) recently revised the age to 34 to 29 Ma from work reported in Vance and others (1987) and Landers and Swanson (1989). The beds include laharic deposits and tuff beds (Fig. H-21) and might be correlative with the Ohanapecosh Formation. In fact, Vance and others (1987) interpreted these as the distal equivalent of beds in the upper part of the Ohanapecosh Formation. You'll pass outcrops of tuffs for the next 0.7 mi (1.1 km).

29.1 *46.8* Junction of US 12 with Soup Creek Road (FR 1305) northwest of highway) and Tieton Road (east end of Tieton Reservoir Road, FR 1200).

29.5 *47.5* Bethel Ridge Road (FR 1500) on the north. The forest road accesses the summit of Bethel Ridge, one of the westernmost folds of the Yakima Fold Belt in this area. Cash Prairie, a bedrock bench west of Bethel Ridge (not visible here), is composed of the Cash Prairie rhyodacite tuff erupted at about 25 Ma from the Mount Aix caldera (Hammond and others, 1994).

You will see many outcrops of volcaniclastic deposits and lava flows related to Tieton volcano (Oligocene–Miocene) on the ridge as you go east on Highway 12. Swanson described the Tieton volcano as a large stratovolcano having a basal shield more than 200 m (656 ft) thick and overlain by 1500 m (4922 ft) of tuff and breccia (Swanson, 1964). Many of the layers of fragmental debris have the steep dips that overall describe a composite volcano (stratovolcano). Swanson and others (1989) described at least 300 m (984 ft) of gently dipping volcanic debris flow deposits, lava flows, and pyroclastic flow deposits "that can be traced nearly continuously into the cone." These deposits likely formed part of an apron at the foot of the volcano. The center of the Tieton volcano lies about 4 to 6 mi (6.5–10 km) east of the summit of Bethel Ridge. Shultz (1988) obtained an age of 26 to 25 Ma for the volcano. Hammond (unpub. data, 2003) confirmed the chemical similarity of its lavas to those of the older Fifes Peak Formation, whose source volcanoes, in order of decreasing age, are Fifes Peaks, Tieton volcano, Timberwolf Mountain, and Edgar Rock.

Bethel Ridge may be cut by a fault. A ridge-top trench several meters in depth and evidence of recent landslide movement, including tilted trees on its north and south slopes, could indicate a sackung. Those adventurous enough to take a side trip up along the forest road can look for the tilted trees of a 'drunken forest' near the top of the ridge.

photo by Beth Norman

Figure H-22. Flow breccias of the Tieton volcano exposed along the north side of US 12 slightly east of MP 169.

photo by Beth Norman

Figure H-23. Pillow lava (gray, center) in palagonite breccia on the north side of US 12 near MP 177. The breccia is associated with the Columbia River Basalt flows. A rock hammer shows scale.

Note that the road to the top is rough, and four-wheel drive vehicles are advisable.

30.5 *49.1* Outcrop of flow breccias of the Tieton volcano (Fig. H-22). Blocks of andesite as much as 30 in. (0.9 m) in diameter crop out in a buff-colored pumice matrix.

31.0 *49.9* An overhanging rock outcrop of flow breccia and andesite is slightly west of the Wildrose picnic area and MP 170.

33.9 *54.5* Enter Rimrock Retreat (elev. 2250 ft or 386 m). This is a popular put-in site for rafters on the Tieton River.

36.1 *58.0* Diamict with angular rocks on the north side of the road likely is the toe of a large landslide from Bethel Ridge. Large landslides are mapped on both sides of the road near here, yet they go almost unnoticed by the casual viewer. Many radial dikes (not shown at map scale) of the Tieton volcano have intruded the rocks of this area. The dikes crop out on both sides of the valley here. Rounded river cobbles and gravels of Quaternary age sit atop the volcaniclastic rocks of the volcano.

37.0 *59.5* Pillow basalts and basalt columns west of MP 176.

37.4 *60.2* Another of the andesite or basaltic-andesite dikes of the Tieton volcano.

37.8 *60.8* Cross the Tieton River. The road cuts through a pillow palagonite breccia (Fig. H-23) that likely formed when part of a lava flow of the Columbia River Basalt Group flowed into impounded water—the flow probably dammed east-flowing streams. Slickensides on the south side of the highway show that the pillow breccia is cut by a fault. However, the fault has not been traced farther than this road cut (Swanson and others, 1989).

38.2 *61.5* MP 177. Cross the Tieton River a second time (if eastbound).

38.6 *62.1* Windy Point Campground. Near here Swanson (1978) mapped 12 distinct flows of the Grande Ronde Basalt of the Columbia River Basalt Group (Fig. H-24). The lower three flows belong to magnetostratigraphic unit R_2 and the upper nine flows are N_1. (See the "Paleomagnetism" sidebar on p. 104 and Fig. 20 on p. 25.)

39.7 *63.9* On the south side of the highway is a viaduct taking irrigation water from a diversion dam west of Rimrock Retreat to agricultural lands in the Yakima River valley. Big blocks on the north are probably part of a landslide deposit.

photo by Beth Norman

Figure H-24. Flows of the Grande Ronde Basalt of the Columbia River Basalt Group near Windy Point Campground.

40.2 *64.7* Eastern boundary of Wenatchee National Forest and the west boundary of the Oak Creek Wildlife area at MP 179.

41.2 *66.3* Landslide deposit (not mapped) near MP 180. Exceptionally well developed jointing in the Tieton Andesite is visible at on the right (Fig. H-25).

42.7 *68.7* Stone stripes, a type of patterned ground, are draped on the hillside here (see Fig. F-9, p. 109).

43.3 *69.7* About 0.4 mi (0.6 km) east of MP 182, there is a good view of the valley-filling Tieton Andesite lava flow overlying Columbia River Basalt.

43.4 *69.8* A micaceous sandstone and siltstone layer between two N_2 flows of Grand Ronde Basalt (Swanson and others, 1989). Swanson (1967) suggested that the metamorphic and plutonic minerals in these interbeds here indicate a northern source area for the stream that deposited them in Grande Ronde time. The mica in these sedimentary rocks, therefore, could be interpreted to be from the ancestral Columbia River or a major tributary. The location of the paleo-Columbia River channel here at the western edge of the Columbia Basin makes geologic sense in that previous researchers have suggested the river was pushed to the margin of the province by the basalt flows. About the sediments, Swanson and others (1989) also noted: "Mixed with the metamorphic and plutonic suite [of minerals] is a pyroclastic suite, including …glass shards, and glass-rimmed plagioclase and mafic minerals." This suite provides clear evidence of explosive activity from Cascade volcanoes during Grande Ronde time 16.5–15.6 Ma (Campbell and Riedel, 1991; see Fig. 20, p. 25).

Figure H-25. Huge columns of the Tieton Andesite flow of Pleistocene age exposed along US 12. The ridge on the horizon is about 580 ft (177 m) above the Tieton River.

44.2 *71.1* On the left at a tight (dangerous) curve to the left, upper entablature and well-developed lower colonnade (columns) of Tieton Andesite sit on rubbly, cobble-rich fluvial deposits of the ancestral Tieton River (Fig. H-26).

44.6 *71.7* Entrance to Oak Creek State Wildlife Area. Note that the exposure on the northwest side of the highway shows the Tieton Andesite only a few meters above river level. Swanson and others (1989) suggested that this implies the base level has not changed much in the approximately 1 m.y. since the andesite was erupted, so little or no downcutting took place—except through the lava flow. Hammond recently redated the flow using Ar-Ar to 1.64 Ma.

45.6 *73.4* Well-developed columns of Tieton Andesite to the south.

46.4 *74.7* Cross the Naches River. This is slightly upstream of its confluence with the Tieton River.

46.6 *75.0* Junction of SR 410 and US 12. From here you can drive east or west on Leg F, joining this leg about 16 mi (26 km) west of where it begins. Reset your odometer if you are proceeding on Leg F. ■

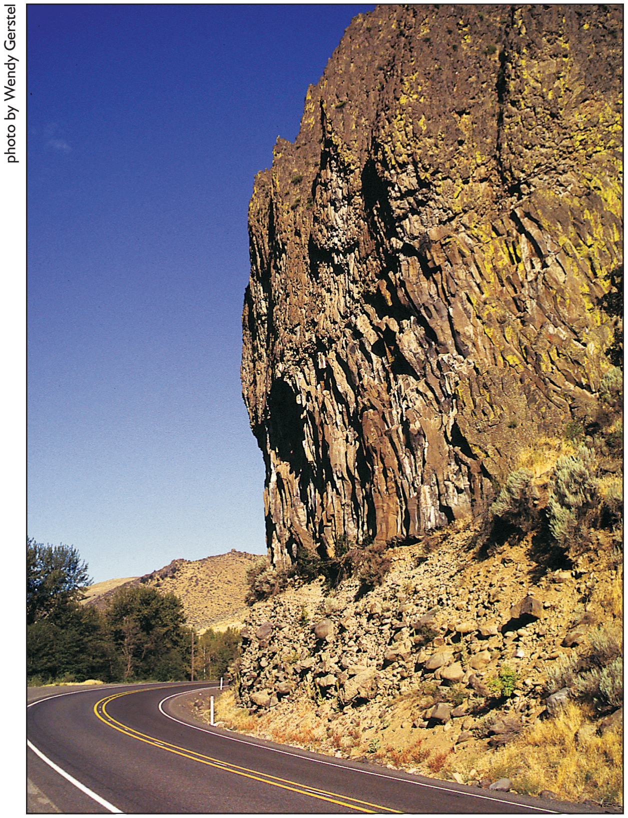

photo by Wendy Gerstel

Figure H-26. Tieton Andesite overlying coarse fluvial gravels. View is to the west along US 12.