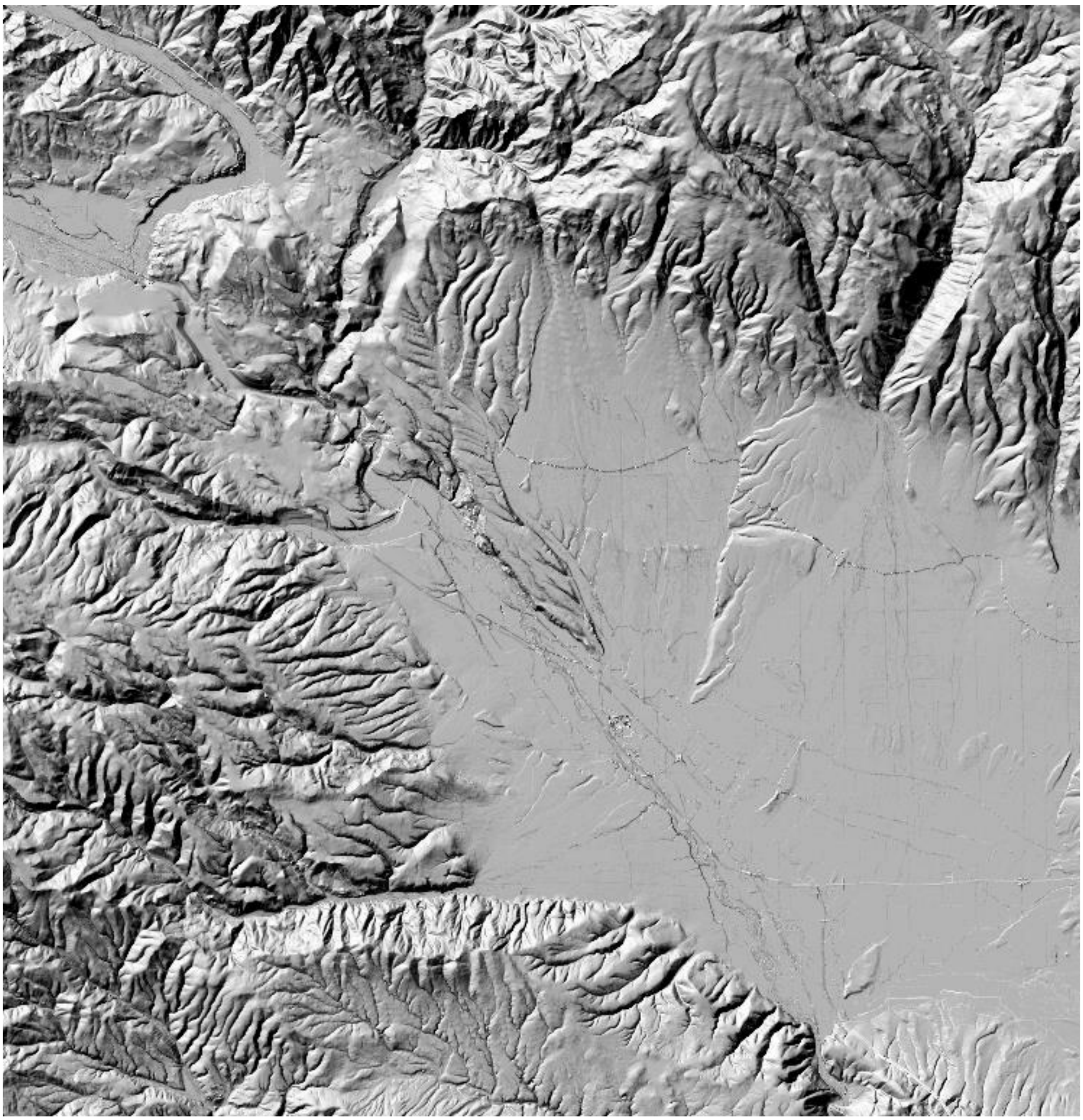
Ellensburg Chapter Ice Age Floods Institute

Margins of the Eastern Cascades: Western Kittitas Basin--Lower Teanaway--Lower Swauk Loop Field Trip



Field Trip Leader:

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05 April 2025

Field Trip Overview

Welcome to the margins of the Eastern Cascades! Ellensburg occupies the Kittitas Basin which lies at the margins of the Columbia Plateau and the Eastern Cascades. This marginal zone is geologic and climatic as well as topographic. We will explore each of these characteristics as we field trip from the Kittitas Basin to the lower Teanaway River and lower Swauk Creek valleys (Figures 1 & 2). In this portion of the Eastern Cascades, we will examine: 1) Ellensburg Formation; 2) glacial outwash terraces; 3) Thorp Gravels; 4) landslides; 5) climate transitions; 6) Teanaway Formation; 7) glacial moraines; 8) Columbia River Basalts; and 9) river channel changes. Throughout our field day, we will emphasize connections between elements of the physical environment and human activity.

Tentative Schedule

9:30am	**CWU Parking Lot O-5**
9:45	**Depart**
10:00	**Stop 1—WA Highway 10 Outcrop**
10:45	**Depart**
11:00	**Stop 2—Hayward Hill Road Viewpoint**
11:45	**Depart**
12:00	**Stop 3— Lambert Road Bridge**
12:45	**Depart to find restrooms in Cle Elum**
1:30	**Stop 4—Swauk Prairie Road**
2:15	**Depart**
2:30	**Stop 5—US 97 Horse Canyon Overlook**
3:15	**Depart**
3:30	**Arrive in Ellensburg**

Stop 1—Overview Topographic Map

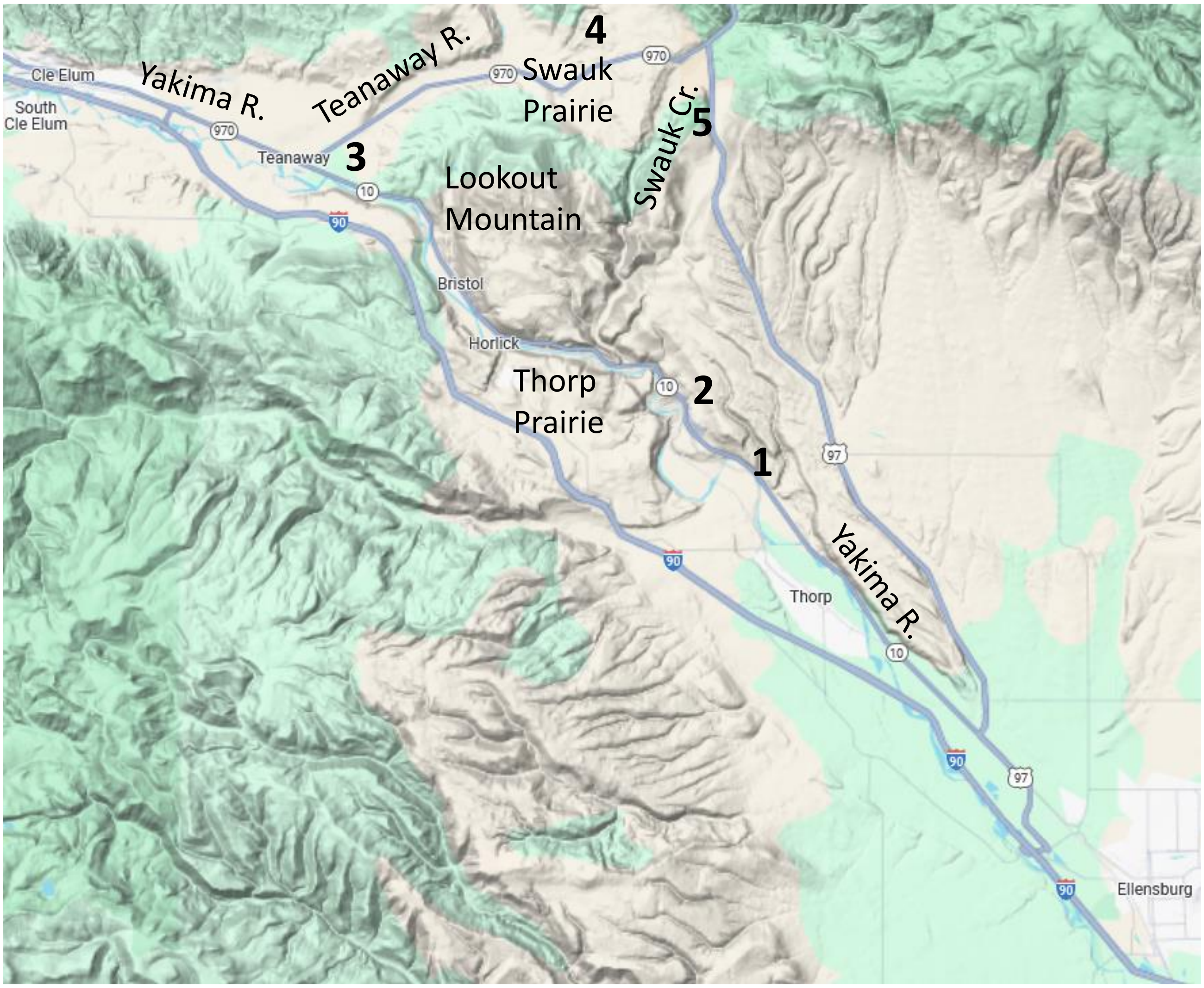
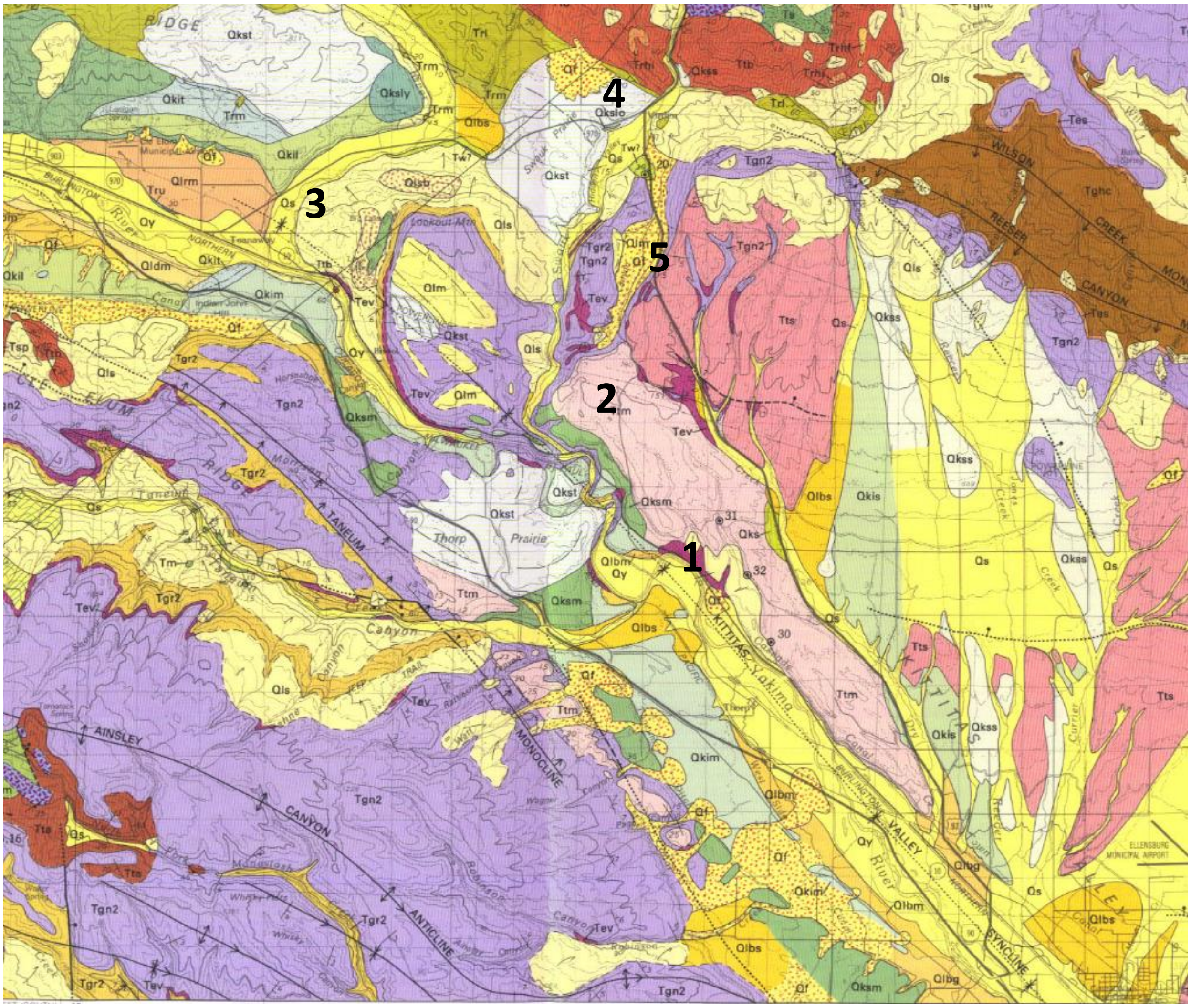


Figure 1. Overview topographic map of a portion of the margins of the Eastern Cascades. Bold numbers indicate approximate locations of field trip stops. Source: Google Maps.

Stop 1—Overview Geologic Map



Select Legend

- Alluvium
- Landslides
- Indian John Outwash
- Indian John Till
- Swauk Prairie Outwash
- Swauk Prairie Till
- Lookout Mtn. Ranch Till
- Thorp Gravels--Mainstream
- Thorp Gravels--Sidestream
- Ellensburg Formation
- Columbia River Basalts
- Columbia River Basalts
- Roslyn Formation
- Roslyn Formation
- Teanaway Formation
- Swauk Formation

Figure 2. Overview geologic map of a portion of the margins of the Eastern Cascades. Bold numbers indicate approximate locations of field trip stops. Source: Tabor & others (1982).

Enroute to Stop 1

<u>CWU to Reecer Creek Road</u>. Exit the north end of CWU's O-5 Parking Lot by turning left onto 14th Avenue and proceeding westward. Bend right to a stop light at the corner of 15th Avenue and Water Street. Proceed straight through this stop light and continue west on 15th Avenue. Follow this street west past Mt. Stuart School where it becomes Dry Creek Road. Follow this road for another ~1 mile to the intersection with Reecer Creek Road. This ~1.6 mile stretch from CWU's O-5 Parking Lot passes across the western portion of the Wilson Creek alluvial fan toe. This fan-shaped, stream deposit in the Kittitas Basin stretches ~7.5 miles from the south side of the Wenatchee Range to the Kittitas Basin floor. Numerous excavations in the area reveal that the fan deposits are characteristically rocky. These rocky deposits remind us of the energy of streams, even at distance from a source.

<u>Reecer Creek Road to US 97.</u> Pass through this intersection and continue northwestward on Dry Creek Road for about 2.3 miles. Along this stretch, the road traverses the toe of the Reecer Creek/Currier Creek alluvial fan. Similar to but smaller than the Wilson alluvial fan, this feature stretches ~6 miles from the base of the Wenatchee Range to here (Figures 2 & 3). These fans and their associated streams have shaped most of the landforms, soils, and agriculture in the northern Kittitas Basin. Also note that Dry Creek Road parallels the former route of the Chicago, Milwaukee, St. Paul & Pacific Railroad. This former rail line is now a Washington State Park "rail trail" known as the Palouse to Cascade Trail. Through Stop 3, our route we will essentially parallel this trail.

<u>US 97 to WA 10.</u> At the intersection of Dry Creek Road with US 97, turn left onto US 97. Travel south just 0.25 miles to the intersection with WA 10.

<u>WA 10 to Stop 1</u>. Turn right onto WA 10 and proceed about 5.7 miles westward to a wide parking area on the left side of WA 10. Park here taking care to park close to other cars so we can all fit in the space. ***The GPS coordinates for this parking spot are 47.096626°N & 120.689240°W.*** *This segment of the route is on the Yakima River floodplain. The escarpment to our right is a remnant of a once much more extensive basin fill (Figure 3). Part of this fill will be the focus of Stop 1. Note how the escarpment looks "fresh" in places. In other places, there are "hummocky" deposits at the base of the escarpment. At still others, the road bends around the escarpment and deposits. In yet other places, concrete block walls appear to support the slopes. All of these characteristics indicate that landslides have been common along this escarpment, even in historical times. And from Ellensburg Ranches Road downvalley for nearly 1 mile, the road parallels a large prehistoric landslide.*

Stop 1—WA Highway 10 Outcrop

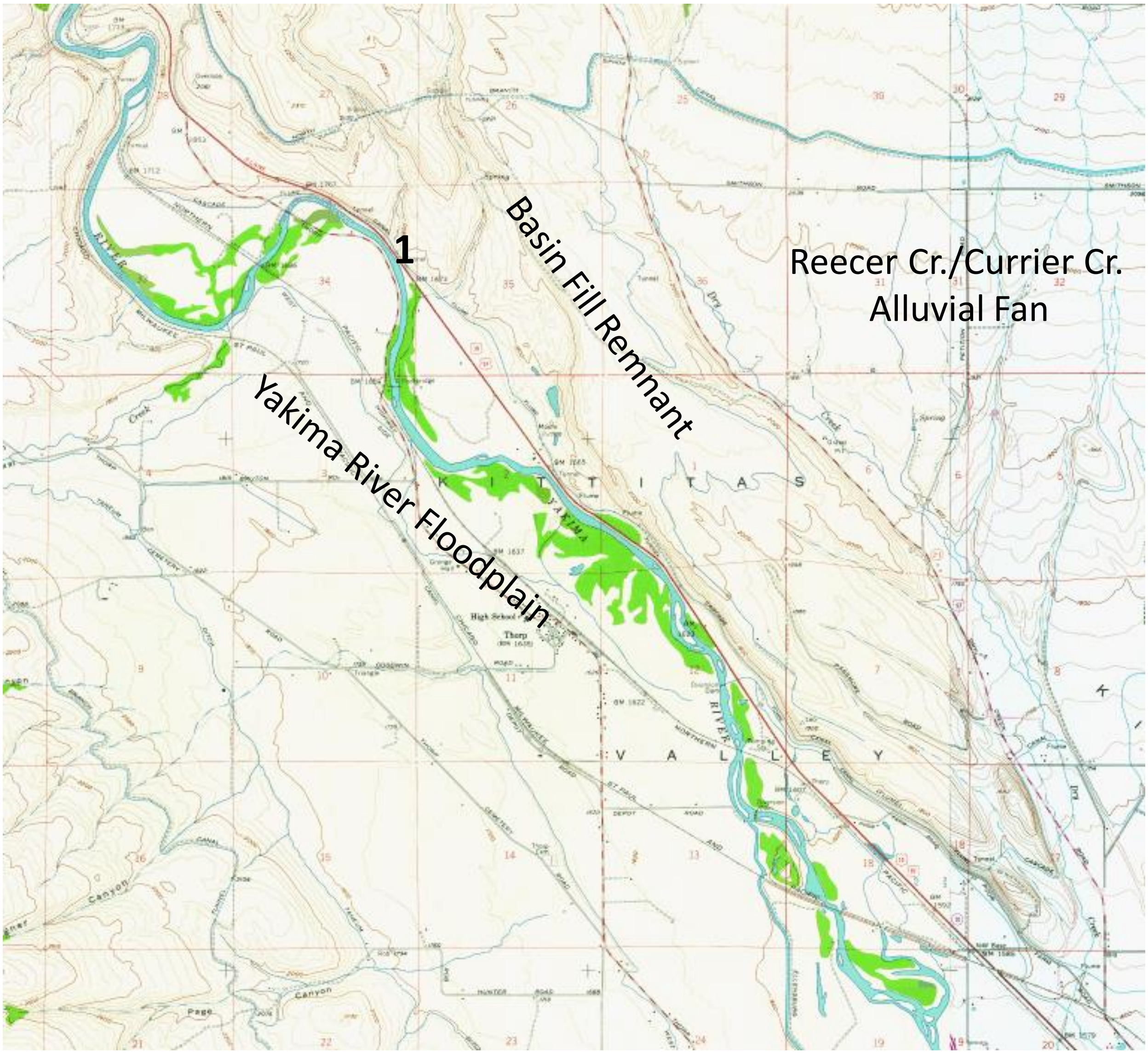


Figure 3. Topography and Yakima River channel patterns near Stop 1. Bold number indicates approximate location of Stop 1. Source: Caltopo.com.

Stop 1—WA Highway 10 Outcrop

Location. We are located between the Yakima River and a large outcrop composed mostly of light colored sedimentary rock. If you decide to cross WA 10 to examine the outcrop more closely, be aware of road traffic and the potential for falling debris from the outcrop.

Climate & Biogeographic Setting. As noted in the overall field trip description, we are in a transitional area climate-wise. Ellensburg is located in a mid-latitude dryland and has an average annual precipitation of ~9 inches (Figure 4). It is a dry place! As a comparison, Seattle receives about 38 inches/year and Spokane gets about 17 inches/year. The primary cause of aridity is the location of Ellensburg in the "rainshadow" (i.e., lee) of the Cascade Range. This rainshadow has likely been in place since the late Miocene-early Pliocene (6-8 million years ago) (Mustoe & Leopold, 2014). However, within that rainshadow, precipitation can vary significantly over a small area. For example, precipitation increases westward within our field trip area approaching 25 inches/year by Stop 3 (Figure 4). Most precipitation occurs in the cooler months (October-March) and is associated with the passage of mid-latitude cyclones (i.e., low pressure "storms"). Native vegetation patterns here reflect precipitation—i.e., outside irrigated and riverside areas, the native vegetation here and eastward to Ellensburg consists of drought-tolerant shrubs and grasses. Conversely, more water-loving coniferous trees are the norm closer to Cle Elum.

The location east of the Cascade Range also results in a somewhat "continental" climate in terms of temperatures. This means that the area is hotter in the summer and colder in the winter (Figure 4) than places that are more "marine"—e.g., Seattle. However, because we are closer to the ocean, we are slightly less continental than places eastward like Spokane.

Wind is common throughout the year with the most common and strongest winds coming from the northwest. The orientation of the upper Yakima River Canyon (just west of here) helps funnel the northwest winds into the Kittitas Basin. Given the dry and windy setting, potential evapotranspiration is estimated to be nearly three times that of precipitation (Donaldson, 1979)!

Each of these climate characteristics play a role, or have played a role, in the landforms of the area. We will reinforce these as we go through the day.

Stop 1—WA Highway 10 Outcrop

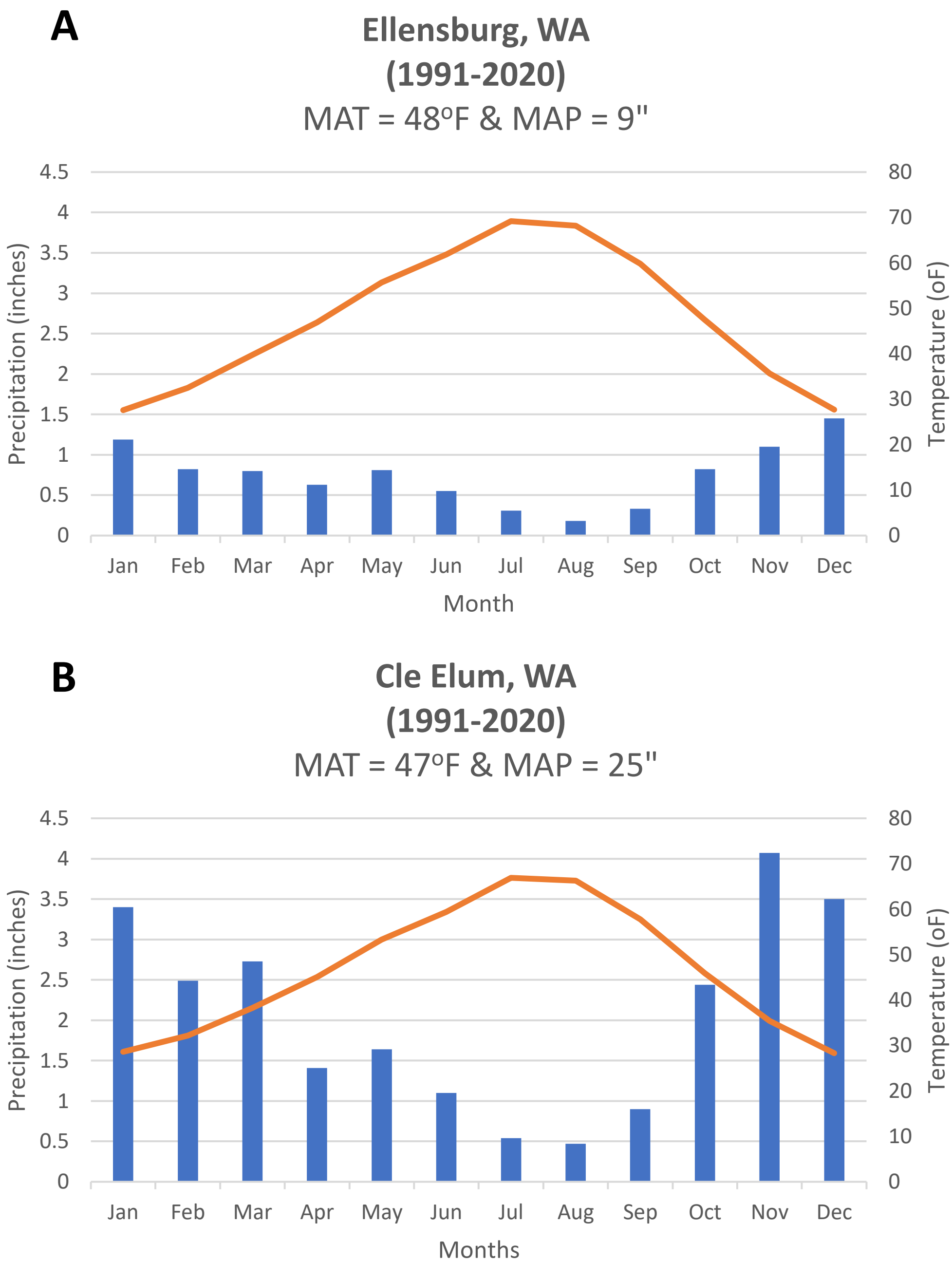


Figure 4. Average monthly precipitation (vertical bars) and temperature (line) at Ellensburg (A) and Cle Elum (B) over the 1991-2020 period. Note especially the differences in precipitation between the two sites. Source: https://www.ncei.noaa.gov/access/us-climate-normals/#dataset=normals-monthly&timeframe=30&location=WA&station=USC00452505.

Stop 1—WA Highway 10 Outcrop

Yakima River Watershed. As noted on the drive to Stop 1, streams have played a key role in shaping this landscape. This is true of tributary streams from the Wenatchee Range (e.g., Wilson Creek) as well as the trunk stream--Yakima River– which flows by just tens of feet to our south. The Yakima River originates from tributaries in the surrounding uplands. The primary tributaries enter upstream of Stop 1 and originate near the crest of the Cascades. River flow depends largely on snowpack and how fast that snow melts in the spring. Reservoirs in three main valleys upstream moderate this runoff and spread it out over summer. We are located atop Yakima River alluvium (i.e., stream deposits) on the modern floodplain (Figures 2 & 3). The Yakima River through this area could be classified as having a "meandering channel" (Figure 3). Such channel are relatively stable over time and are characterized by channel incision. Our stop is on the erosional "cutbank" of the meander. It is because of this erosion that the outcrop here formed.

Geologic Substrate & Orientation. The bedrock underlying the area is Columbia River Basalt but those units are not readily visible here (Figure 2). We will see them at stops 3, 4 and 5. Instead, what we see here are several units that we could call "basin fill" tied to the ancestral Yakima River and various tributary streams. These include the Ellensburg Formation and the overlying Thorp Gravels (Figure 2). The origin of the Kittitas Basin is tectonic activity primarily via folding. Therefore, the Kittitas Basin is a NW-SE trending downfold (i.e., syncline). We are located very close to the axis of this syncline (Figure 2). This basin was an ideal place to accumulate basin fill.

Ellensburg Formation & Its Distribution. One of the key basin fill units is the Ellensburg Formation which was first named the "Ellensburg Sandstone" by geologist I.C. Russell (1900) for the thick deposits in the vicinity of Stop 1 (Figure 2). In addition to sandstone-like layers, the Ellensburg Formation consists of siltstone and conglomerate layers, containing ample volcanic materials (Tabor & others, 1982). Other prominent outcrops of Ellensburg Formation may be found in the Kittitas Basin on Craigs Hill in Ellensburg, Potato Hill along I-82 in the southern Kittitas Basin, and south of Horse Canyon in the northern Kittitas Basin (Figure 5). The Ellensburg Formation outcrops elsewhere in Central Washington including the Naches and Tieton drainages to the south, and in the vicinity of Rock Island to the east.

Stop 1—WA Highway 10 Outcrop

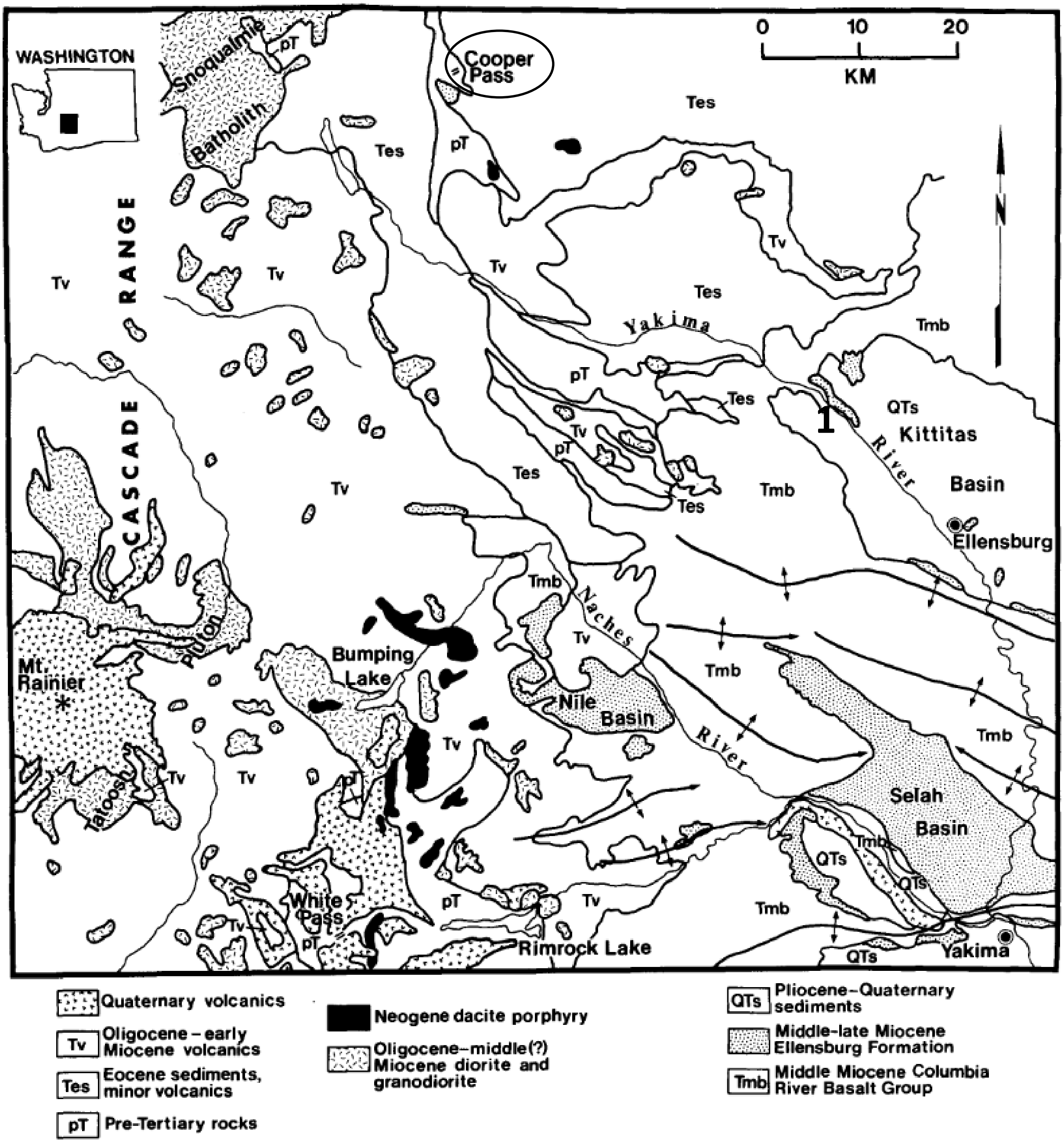


Figure 5. Geologic map of the central portion of the Eastern Cascades. Note the stipled units that represent the Ellensburg Formation and the black units that represent potential sources of Ellensburg Formation deposits. Of particular interest are the small areas of dacites in the vicinity of Cooper Pass (circled) in the Upper Yakima River Basin. Bold number indicates approximate location of Stop 1. Source: Smith & others (1988).

Stop 1—WA Highway 10 Outcrop

Figure 6. East end of Ellensburg Formation outcrop near Thorp along WA 10. Note dilute stream deposits, paleosol, and overlying Thorp Gravels. Pyroclastic flow, lahar, and hyperconcentrated flow deposits are more evident on western portion of outcrop. Source: Author photo, 28 February 2025.

Ellensburg Formation Subdivisions. At first glance, you may see little variety in the outcrop (Figure 6). However, by looking more carefully, you can see differences based on "bedding" (i.e., layers), contacts between layers, composition, grading (i.e., sediment size increasing or decreasing with depth in a unit), topography of the outcrop, texture, and color. Carley Preator, a CWU undergraduate student worked with CWU Geology Professor Bre MacInnes to interpret and date this outcrop. She identified (from bottom to top) a "pyroclastic flow" (i.e., deposit made by an avalanche of hot air and volcanic debris), a "lahar" (i.e., volcanic mudflow), "dilute stream flow" (i.e., normal stream flow), a "hyperconcentrated flow" (i.e., sediment-rich flow of sediment and water that is intermediate to water and debris flow), then more dilute stream flow. A "paleosol" (i.e., ancient buried soil) is present within the dilute stream flow deposits (Preator, 2024) (Figures 6 & 7).

Stop 1—WA Highway 10 Outcrop

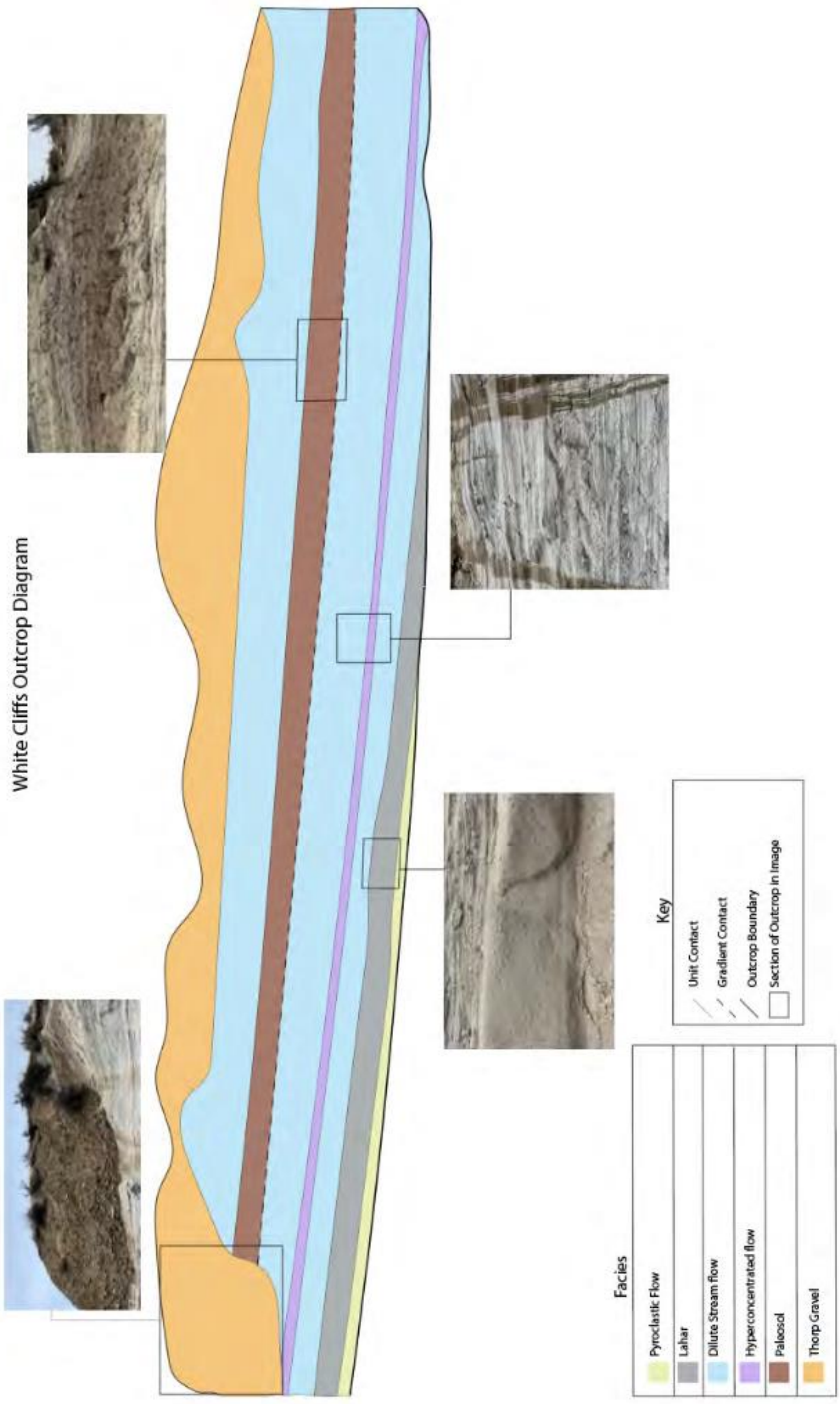


Figure 7. Stratigraphy of outcrop along WA 10 near Thorp. Source: Preator (2024).

Stop 1—WA Highway 10 Outcrop

Ellensburg Formation Age. The Ellensburg Formation overlies and is interbedded with the Grande Ronde Basalt of the Columbia River Basalts (Smith & others, 1989). Therefore, it is of the same age and younger than the ~16.5 to ~15.6 Ma Grande Ronde Basalts. A date from the vicinity of Stop 1 is about 10.5 Ma (Smith & others, 1989), and more recently from the pyroclastic flow at this outcrop dated at 10 +/- 0.2 Ma (Preator, 2024). These relative and absolute dates indicate that volcanic-rich debris was deposited as the Ellensburg Formation in the Kittitas Basin between about 16.5 and 10 Ma. This suggests that the Kittitas Basin was here in some form at the time (Tabor & others, 1982).

Ellensburg Formation Sources. A close-up examination of the Ellensburg Formation reveals that it contains ample volcanic debris ranging from ash to lapilli (i.e., larger than ash, smaller than "blocks"). Composition is mostly dacite which is intermediate to more familiar andesite and rhyolite. Dacite is the fine textured equivalent of plutonic granodiorite. What was the source of this volcanic debris? Based on composition, age, and paleocurrent data, the volcanics at and near Stop 1 appear to have originated in the vicinity of Cooper Pass to the northwest of here (Smith & others, 1988) (Figure 5). These rocks have been mapped as the "Volcaniclastic Rocks of Copper Pass" in Tabor & others (2000) and they lie ~35 straight line miles away from here. The path that the sediments took to reach here is not known.

The Ellensburg Formation was a prodigious basin filler because of its volcanic origins. This is so because volcanic eruptions essentially create sediment instantly. Further, existing volcanic debris is often poorly consolidated to unconsolidated and poorly vegetated because of prior eruptive activity. All of this leads to ample sediments available to be transported (Smith, 1991).

Enroute to Stop 2

<u>WA 10 to Hayward Hill Road</u>. Continue west on WA 10 for ~1.1 mile. In doing so, you will have ascended and driven over a prominent river terrace. We will discuss this more at Stop 2. Turn right onto gravel Hayward Hill Road and ascend this curvy road for about 1.2 miles. Park alongside the road here for a really big picture view of the western Kittitas Basin. **GPS coordinates are 47.124781°N & 120.715088°W.**

Stop 2—Hayward Hill Road Viewpoint

Location. We are located atop Hayward Hill just downslope of the Cascade Field and Stream Club shooting range (Figure 8). We will remain on the side of the road here because private land borders both sides of the road. Manastash Ridge is the ridge on the south and southwest skyline, and the Kittitas Basin lies between here and Manastash Ridge (Figure 9).

Thorp Gravels. We are located atop Thorp Gravels, a thick gravel deposit that caps ridges in the Kittitas Basin (Figure 2). The Thorp Gravels consist of two main subunits—Thorp mainstream and Thorp sidestream. The sidestream subunits are composed primarily of Grande Ronde basalts eroded from the Wenatchee Range to the north. The mainstream rocks consist of reworked Ellensburg Formation intermediate volcanic rocks. We are on the mainstream subunit. The Thorp mainstream dates to 3.8-4.5 my (Tabor & others, 1982). Note the highly weathered nature of some of the Thorp Gravels present along the road.

Thorp Gravels Origins & Ages. Interpretations of the Thorp Gravels have changed dramatically over time reflecting the world of science where we constantly learn because new tools help us answer new questions. Originally, this unit was mapped as part of the Ellensburg Formation (Smith, 1904). Later, because it was so highly weathered and appeared to be part of "lateral moraines" (i.e., ridges formed on lateral margins of glaciers) and included possible "erratics" (i.e., out of place rocks deposited by glaciers), it was described as Porter's (1976) oldest glacial deposit (i.e., Thorp Drift). Still later, Thorp Gravels were thought to record stream aggradation (i.e., deposition) on the basin floor caused by the uplift of the anticlines south of the Kittitas Basin (Waitt, 1979). More recently, it has been suggested that Thorp Gravel terraces in the canyon south of Ellensburg plus diminishing thickness of Thorp Gravels from northwest to southeast to suggest that upstream uplift or glaciation or a combination of both led to basin aggradation (Smith, 1988). Recent mapping still raises the question of a possible glacio-fluvial origin (Sadowski & others, 2020).

Stop 2—Hayward Hill Road Viewpoint

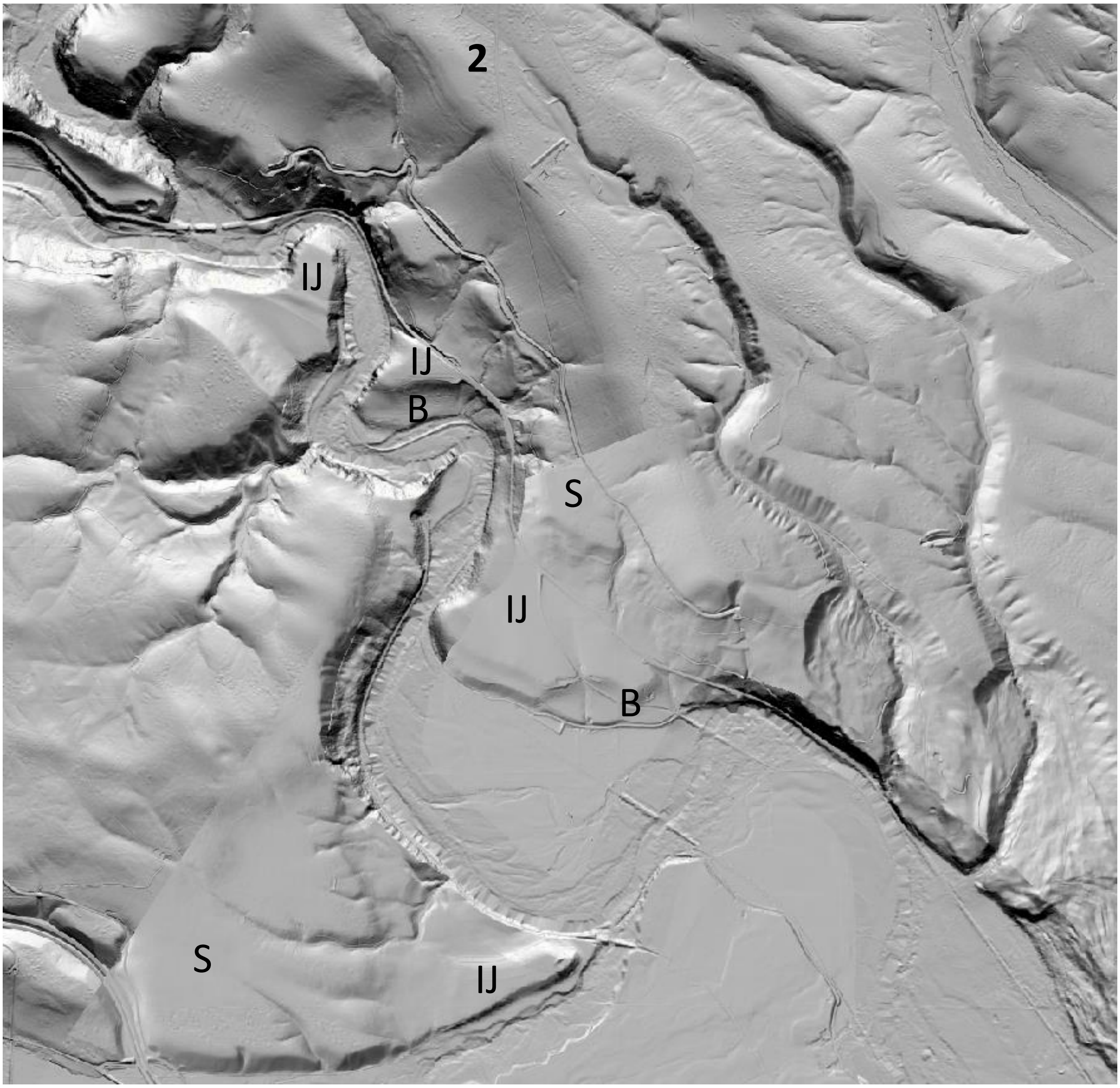


Figure 8. Lidar view of landscape in vicinity of Stop 2. The letters mean the following glaciations: S = Swauk Prairie, IJ = Indian John; B = Bullfrog. Bold number indicates approximate location of field trip stop. Source: Washington Lidar Portal.

Stop 2—Hayward Hill Road Viewpoint

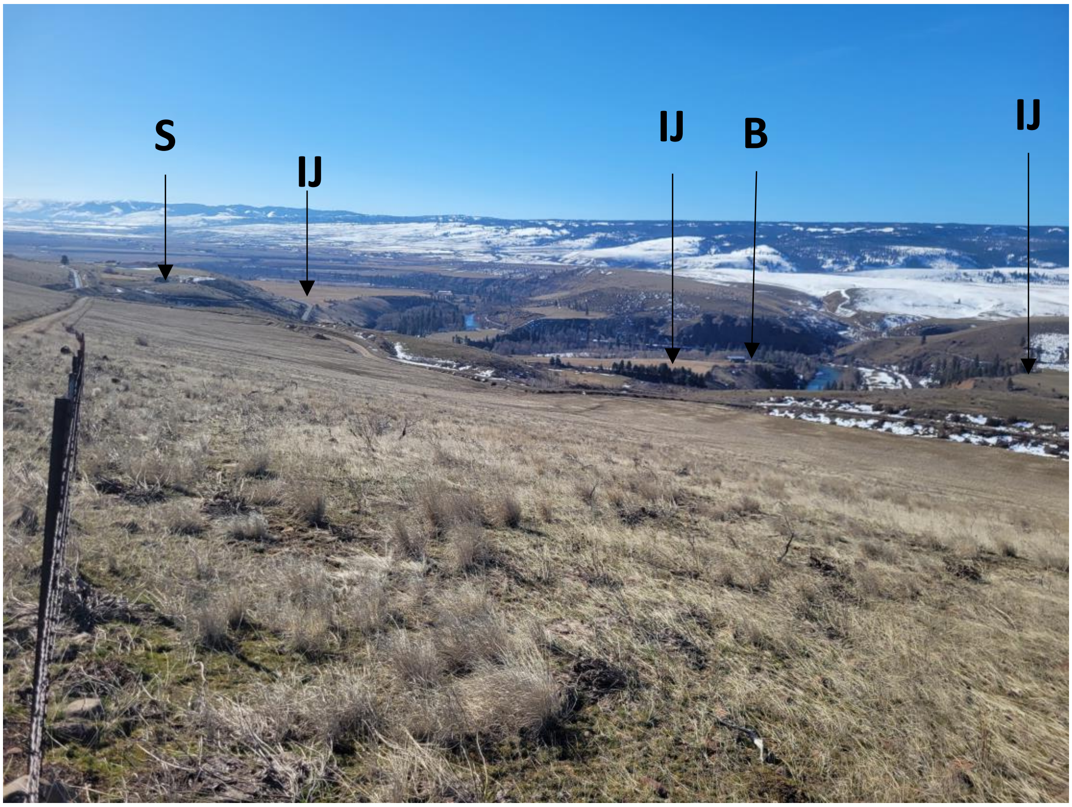


Figure 9. View from Hayward Hill Road southward toward Manastash Ridge, Western Kittitas Basin, and Thorp Prairie. Note the terraces in the foreground. These include: IJ = Indian John, S = Swauk, and B = Bullfrog. Source: Author photo, 28 February 2025.

Glaciation. The "Pleistocene" (i.e., ~2.6 million to ~11,600 years ago) ice ages included numerous periods of glacial advance and retreat. The glacial periods resulted from lower temperatures and possibly increased precipitation. In the Upper Yakima River Basin, the resulting glaciers were not ice sheets; rather, most originated as small glaciers that formed in "cirques" (i.e., amphitheater-shaped basins high on mountain sides). The resulting "cirque glaciers" grew, spilling out of cirques to fill valleys and form "valley glaciers". These valley glaciers extended down the main valleys of the Yakima River drainage, often merging to form larger valley glaciers. I.C. Russell was the first to map the extent of glaciers in the Upper Yakima River Watershed (Figure 10). These glaciers left landform evidence in the form of cirques in the headwaters areas and moraines and outwash deposits further downvalley (Figure 11).

Stop 2—Hayward Hill Road Viewpoint

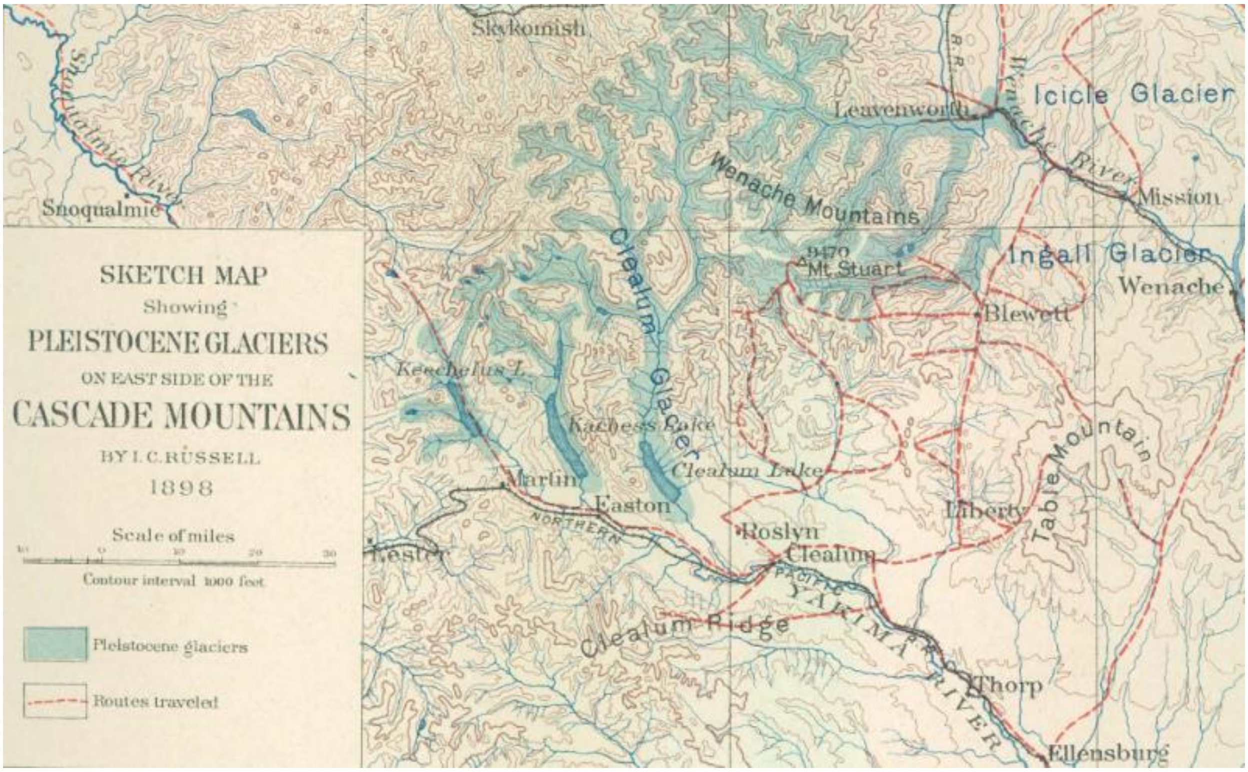


Figure 10. An early look at glaciation in the Upper Yakima River Watershed. Note the absence of observed glacial evidence downstream of lakes Cle Elum, Kachess, and Keechelus. Source: part of Plate XVIII in Russell (1900).

Multiple glaciations. University of Washington geologist Stephen Porter greatly refined Russell's early mapping and added age information on glaciation (Porter, 1965, 1969, 1976; Kaufman and others, 2004). These glaciations were differentiated by their relative positions, moraine topography, soil development, and percentages of surficial boulders.

Porter's work and subsequent removal of one of Porter's glaciations by Waitt (1979) resulted in the following seven upper Yakima Valley Pleistocene glaciations (from oldest to youngest) (Figure 12 & Table 1):

Stop 2—Hayward Hill Road Viewpoint

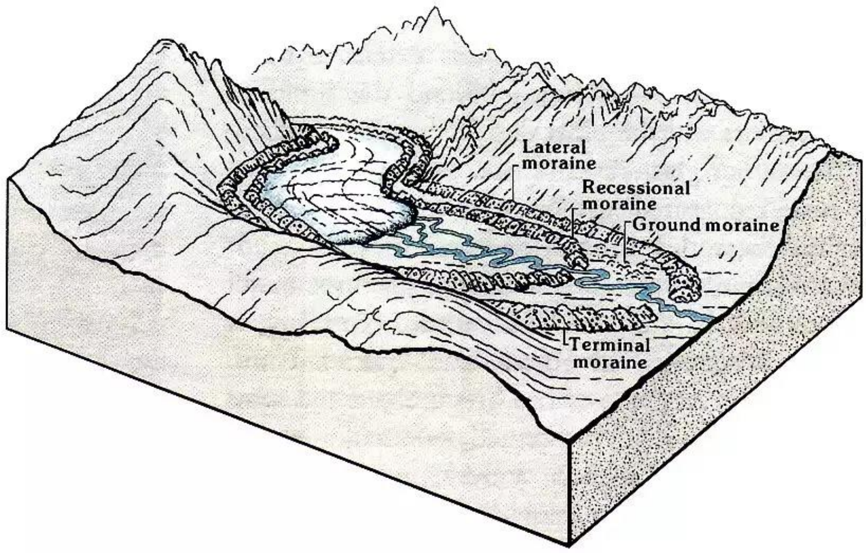


Figure 11. Alpine glacier moraines. Source: https://serc.carleton.edu/details/images/181751.html

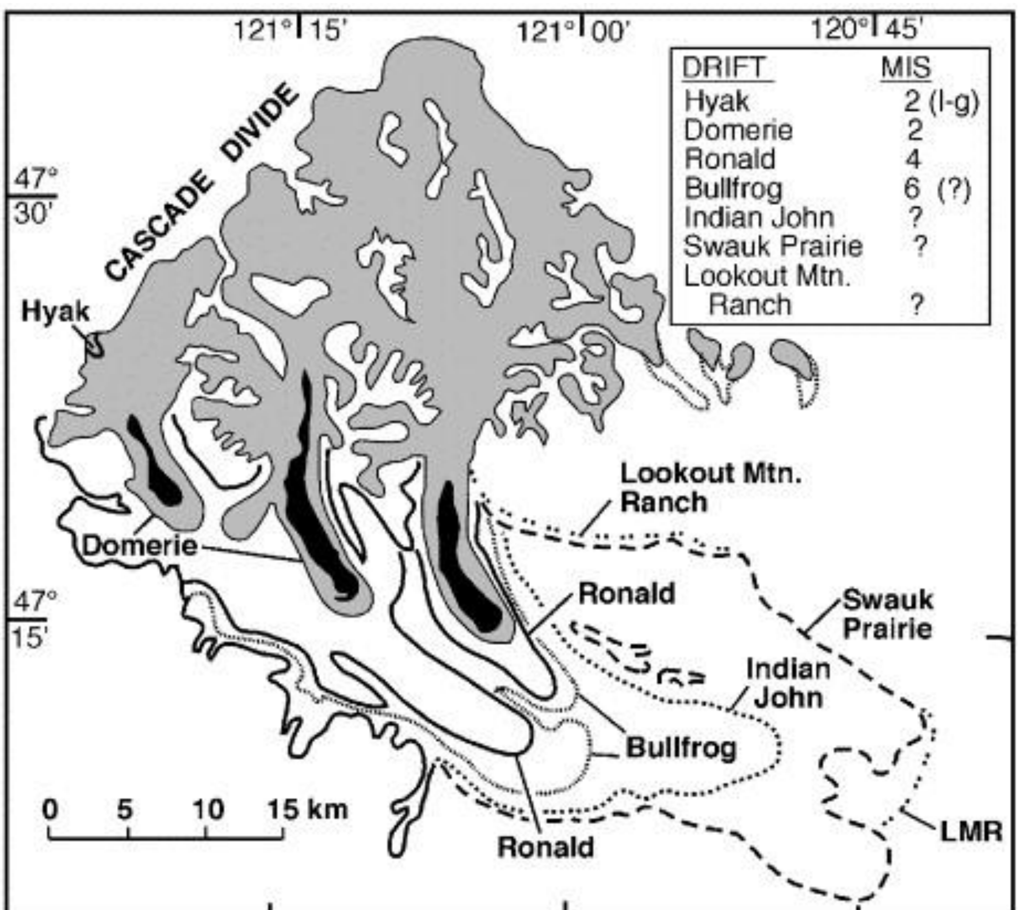


Figure 12. Extent and inferred ages of glaciation in Upper Yakima River drainage. From Kaufman, Porter, and Gillespie (2004, p. 82)

Stop 2—Hayward Hill Road Viewpoint

Table 1. Past Yakima River watershed glaciations. Sources: Porter (1976); Swanson & Porter (1997).

Drift	Subdrift	Avg. Length (mi) & Extent	Area (mi^2)	Maximum Thickness (ft)	Age
Lakedale	Hyak	~3 mi (to Snoqualmie Pass)	54	919	~11,000 ^{14}C yr BP
Lakedale	Domerie	~21 mi (to downstream ends of lakes Keechelus, Kachess & Cle Elum)	209	1181	~16,000 ^{36}Cl yr BP
Lakedale	Ronald	~29 mi (to near Ronald)	255	1345	66,000 ^{36}Cl yr BP
Lakedale	Bullfrog	~31 mi (to near Cle Elum)	278	1395	>80,000 ^{36}Cl yr BP
Kittitas	Indian John	~40 mi (nearly to Indian John Rest Area)	338	1640	>80,000 ^{36}Cl yr BP
Kittitas	Swauk Prairie	~44 mi (to Swauk & Thorp prairies)	419	2083	>600 Ka
	Lookout Mountain Ranch	To Horse Canyon?	>419	>2083	

Recent Glaciers. Airphoto analysis reveals that the numbers and area of glaciers in the Upper Yakima River Watershed have decreased dramatically since the 1970's due to temperature increases. At present, there are less than five very small glaciers high in the watershed's headwaters near Lemah Mountain and Chimney Rock west of Cooper Pass.

Outwash Deposits. Glaciers characteristically generate abundant meltwater. This meltwater is loaded with silts, sands, and gravels, and is collectively known as "outwash". The areas downvalley of moraines are typically mantled in thick blankets of outwash deposits. Outwash may often be traced directly back to the end moraine of a glaciation. Outwash, like moraines, may also be dated through various means. When post-glacial incision occurs it isolates the outwash deposits as "terraces". This incision occurs because streams generally transport less sediment during interglacials than they do during glacial periods therefore their energy is used to incise rather than transport.

From our Stop 2 viewpoint, we can see numerous terraces (Figures 8 & 9). However, there are only 3 different aged Pleistocene terraces in view. The prominent terrace below us on which WA highway 10 passes over is composed of Indian John outwash. Swauk outwash is just upslope of that and we crossed it as we drove up Hayward Hill. Bullfrog outwash is present in several small nearby terraces.

Enroute to Stop 3

<u>Stop 2 to WA Hwy 10:</u> From Stop 2, turn around on Hayward Hill Road and return to WA highway 10.

<u>WA Hwy 10 to Taylor Road</u>: Turn right onto WA highway 10 and head west for ~7 miles to Taylor Road. Soon after joining WA highway 10, the road descends into the "upper canyon" of the Yakima River. Because of the bedrock confines of the canyon, this stretch of the Yakima River is quite different from that around Stop 1. Note the Grande Ronde Basalt flows forming the canyon walls. Given the amount of outwash stored in the lower parts of this canyon, we can assume this canyon has been around since before the Indian John Glaciation.

Near where Swauk Creek joins the Yakima River, the floodplain is covered by Oregon White Oak, a species that is also found in the Naches and lower Tieton river valleys as well as the Satus Creek valley to the south. Why is it here and not in other nearby valleys? And how long has it been here?

Mass wasting (e.g., landslides) is evident in all forms on our drive through the steep-walled canyon. Steep slopes, unstable geology, and leaky irrigation canals and ditches have all likely played a role in mass wasting here. Add in wet seasons and wet years and you have a great recipe for mass wasting. Numerous mass wasting events have occurred through this upper canyon in historical times. A quick look at past Ellensburg Daily Record articles identifies at least five significant mass wasting events since the 1950's that damaged the highway, railroad or irrigation canals through the area. Perhaps the most notable of the recent events occurred near the old Northern Pacific rail stop of Bristol in April 1995. Here, the Bristol Flats landslide took out a 200 foot section of the Kittitas Reclamation District canal leaving more than 59,000 acres of farmland without water for approximately two weeks (Johnston, 1995; 1996).

Outcrops of Ellensburg Formation are present on the north side of the highway along the base of Lookout Mountain.

<u>Taylor Road to Lambert Road</u>: Turn right onto gravel Taylor Road. Once on this road, follow it north and northwest for ~0.9 miles to its junction with Lambert Road. The hummocky surface through which Taylor Road passes is from a giant landslide on the west side of Lookout Mountain. We will focus on this at Stop 3.

<u>Lambert Road to Stop 3</u>: At the junction of Taylor and Lambert roads, turn left onto paved Lambert Road and head west for less than 0.4 mile. We are on the floodplain of the Teanaway River. Park on either side of the road before or after the bridge. Make sure that your vehicle is far enough off the road for local traffic to pass through. Also make sure not to block any of the driveways along the road. ***GPS coordinates: 47.174952°N & 120.835610°W.***

Stop 3—Lambert Road Bridge

Location. We are located on the Teanaway River Floodplain about 0.6 mile upstream of its junction with the Yakima River (Figure 13). Lookout Mountain is to the east. South Cle Elum Ridge, the Yakima River Valley, and Cle Elum Ridge lie to the west.

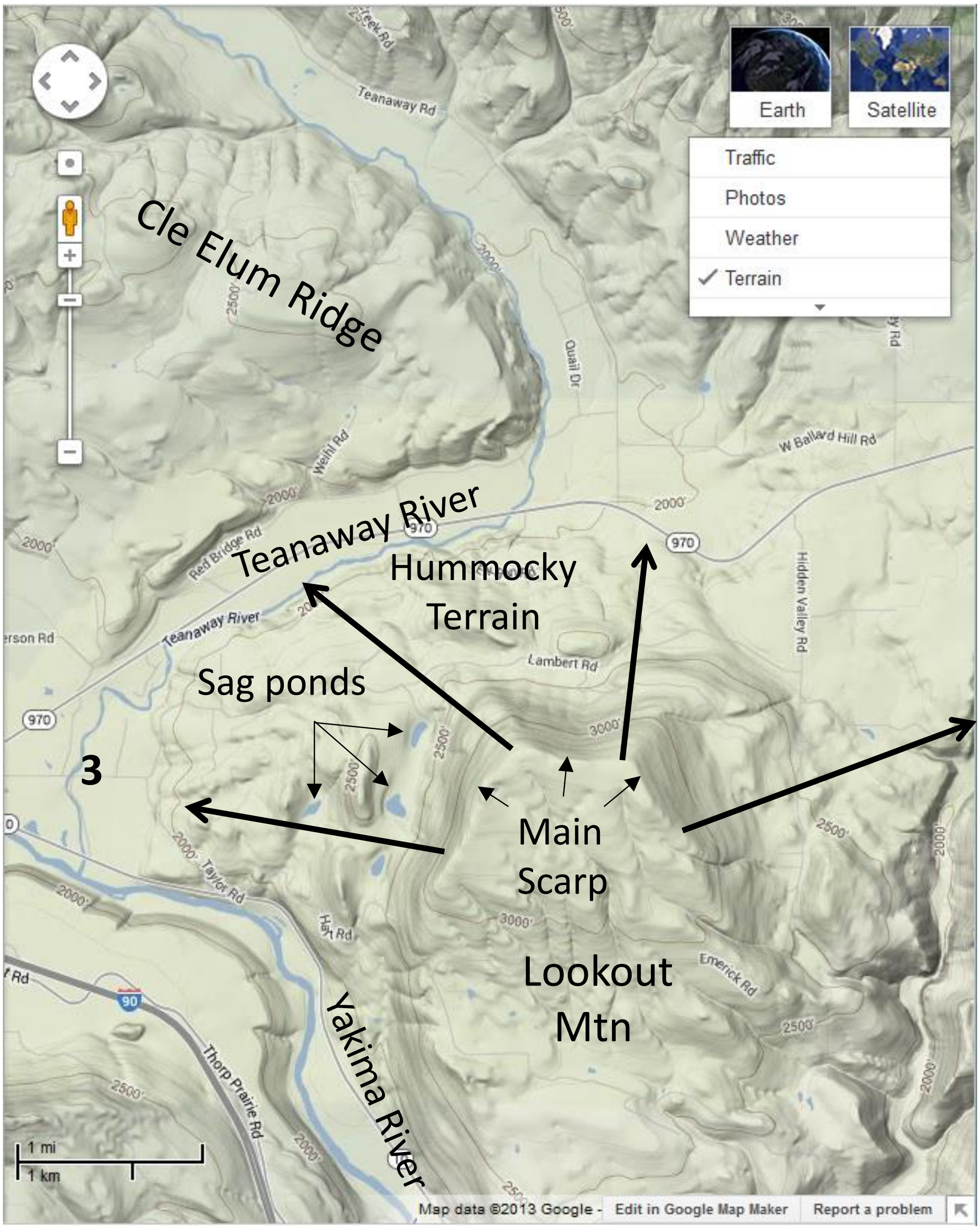


Figure 13. Rotational slide evidence on Lookout Mountain. Note how the Teanaway River has flowed around the toes of the slides. Source: Google Maps.

Stop 3—Lambert Road Bridge

Bedrock Geology. The bedrock in the vicinity of Stop 3 is complex! Igneous, sedimentary, and metamorphic rocks ranging from Jurassic to Miocene in age are present in South Cle Elum Ridge. The rocks have been folded into the Taneum Monocline, a western part of the Yakima Fold and Thrust Belt. Cle Elum Ridge is simpler consisting of Eocene sedimentary rocks of the Roslyn Formation. The intervening Yakima River Valley follows a syncline and is mantled by a variety of alluvial and glacial sediments (Tabor & others, 1982).

East of Stop 3, the geology is primarily Columbia River Basalts, particularly the Grande Ronde Basalts (Tabor & others, 1982). At this stop, we are very near the western extent of CRB's in the area (Figure 14).

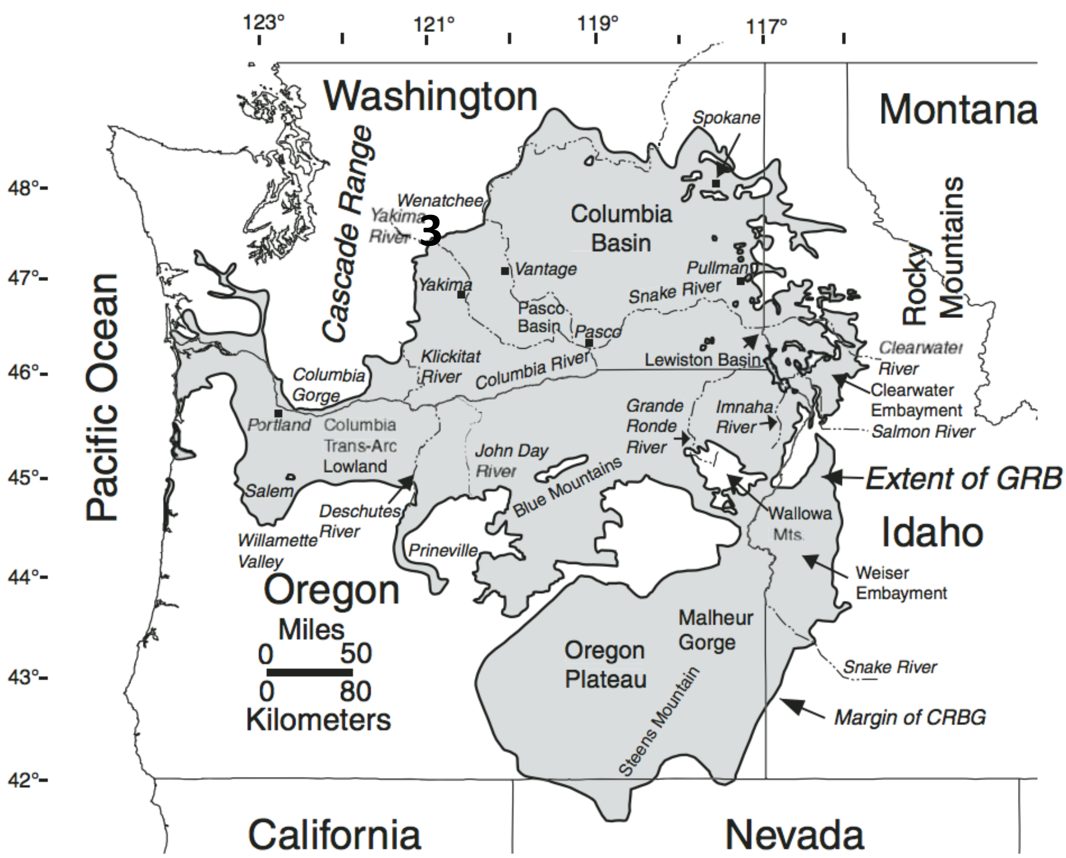


Figure 14. The extent of the Columbia River Basalt Group in Washington, Oregon, Idaho, and northern Nevada. Bold 3 indicates approximate location of field trip stop. Source: USGS Cascade Volcano Center (https://www.usgs.gov/media/images/columbia-river-basalt-group-map-shows-main-regions-basalt-exposu).

Stop 3—Lambert Road Bridge

Teanaway River Discharge. You are seeing the Teanaway River when it is typically near its highest "discharge" (i.e., flow) of the year (Figure 15). This pattern exists because of our wet winter/dry summer climate. As you examine the river, note the evidence in stream sediments, stream side vegetation, and human structures for even higher flow during other years.

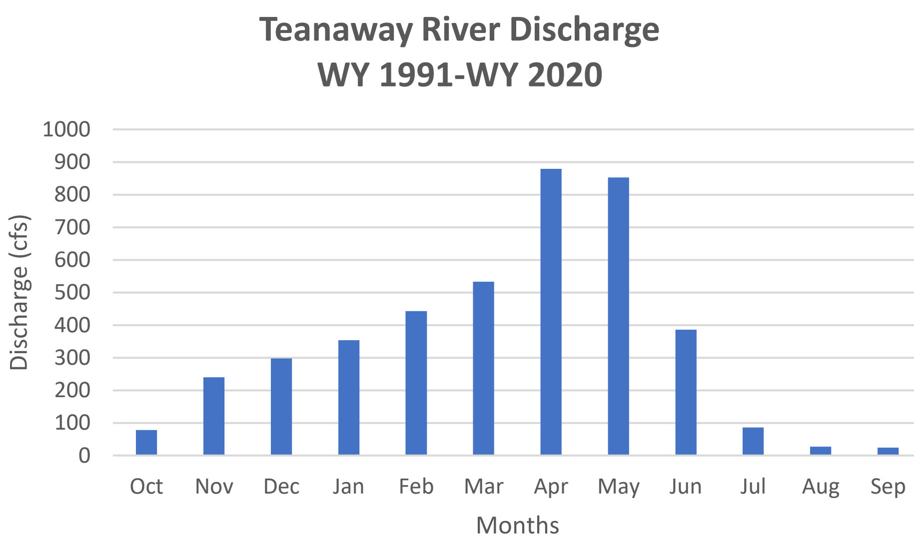


Figure 15. Average Teanaway River discharge measured below the three forks of the river over the 1991-2020 water years. Source: https://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html .

Flashy Teanaway River. The Teanaway River is an unregulated river that may be thought of as "flashy" in terms of its discharge. This variation results from extreme precipitation events occurring on steep topography and thin soils in the headwaters, and a lack of ponds, lakes, and wetlands in the lowlands to buffer these flows. The transitional location (near the Pacific Ocean but inland) means that the Teanaway, like other rivers in the Yakima River Basin, takes on the characteristics of marine and continental watersheds in the timing of its floodwaters. Marine watersheds have significant fall and winter flooding associated with rain events while more continental watersheds often flood in May and June as snow melts at higher elevations (Kinnison, 1952).

The mainstem Teanaway River has experienced floods in 12 of the years between 1991-2020 (Figure 16). Approximately one-half of these occurred in the late fall/winter associated with significant rain-on-snow events while the other half happened in spring with warm temperatures and a large mountain snowpack.

Stop 3—Lambert Road Bridge

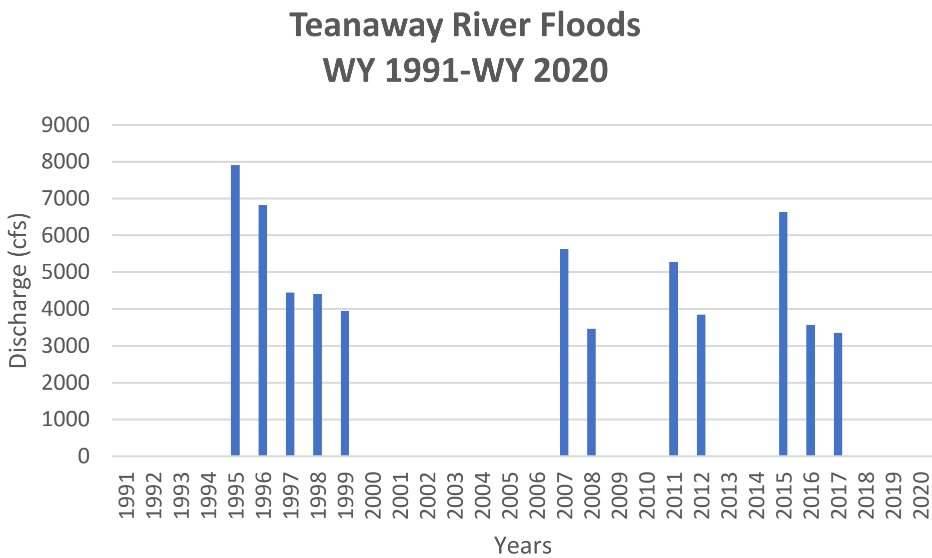


Figure 16. Teanaway River floods, 1991-2020 water years. Source: https://www.usbr.gov/pn/hydromet/yakima/yakwebarcread.html .

River and Floodplain Morphology. River and floodplain morphology is shaped primarily by high discharge (i.e., flood) events. The morphology of the lower Teanaway River floodplain is that of an alluvial meandering stream (Figure 17). Rounded gravels characterize the alluvial deposits and are a mix of the various rocks of the watershed. The key features of such a river are "point bars" characterized by lower velocities and deposition, and "cutbanks" (like we saw at Stop 1) associated with higher velocities and erosion. Both features are visible from the bridge. Over time, these features migrate downstream. During floods new channels form as we see to the east of Stop 3 (Figure 18), often later to be abandoned at low flow.

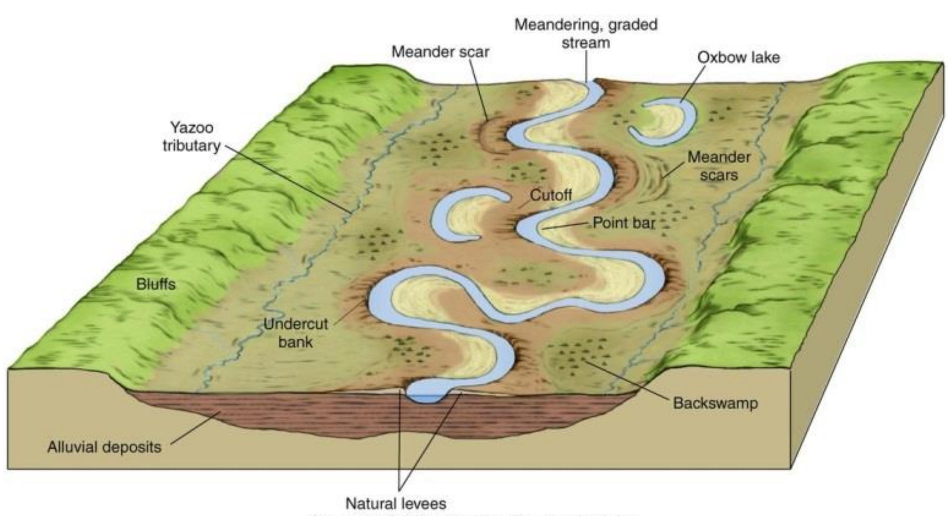


Figure 17. Diagram of a typical meandering stream system. Source: http://thebritishgeographer.weebly.com/river-landforms.html

Stop 3—Lambert Road Bridge

Figure 18. Vertical aerial perspective of meandering lower Teanaway River and Stop 3. Abandoned channels indicated by arrows. Source: Google Earth Pro, 07/01/2017.

Stop 3—Lambert Road Bridge

Lookout Mountain Landslide and Rockfall. From here, we have a great view of the Lookout Mountain landslide. This landslide was first recognized by Russell (1900) and Smith (1904). It is a large, "rotational landslide" (Figure 19). Evidence for this rotational slide includes: 1) the prominent escarpment (i.e., main scarp) high on Lookout Mountain; 2) the large, backtilted blocks and associated minor scarps and ponds just downslope of the escarpment; and 3) the hummocky toe that extends to the Teanaway River near here (Figures 13 & 18). At least four "sag ponds" are impounded within the large slide blocks. Subsequent rockfall occurred from the near vertical, bare, Grande Ronde basalt face of the main scarp.

Age. How old is the feature? First, I don't know if the slide occurred all at once or piecemeal over time. Second, I don't know of any dates on the landslide so I can only address its age in a relative sense. Smith (1904) recognized a river terrace atop the middle portion of the slide. Tabor and others (1982) attributes that terrace to the Swauk Prairie-age glacial outwash deposits. Recall that Swanson and Porter (1997) estimate that Swauk Prairie deposits are >600,000 years old so this slide is potentially more than one-half million years old! This is hard to believe given that the feature is so well-preserved. Perhaps this preservation is due to the semiarid climate and the hard basalts so little degradation has occurred over time.

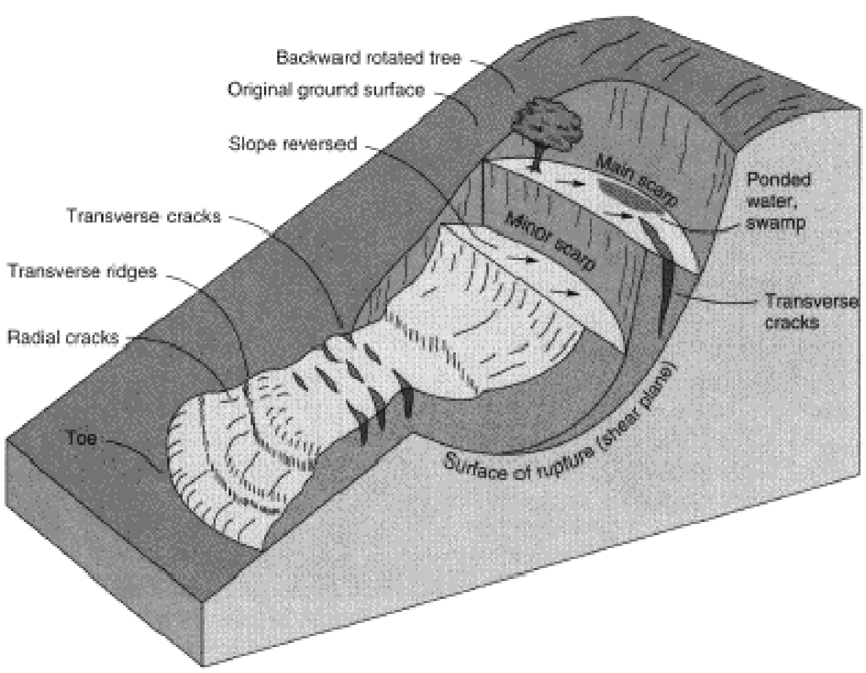


Figure 19. Model of a rotational slide. Source: http://www.ussartf.org/landslides.htm

Stop 3—Lambert Road Bridge

Causes. What caused this rotational slide? Weak "interbeds" (e.g., Ellensburg Formation) between the Columbia River Basalts likely played a role as did a wetter climate at the time of the event. Perhaps a large earthquake triggered such a large slide. A large lake impounded in the lower Teanaway River Valley by glaciers or moraines may have saturated substrates causing the failure of this slope (Tabor & others, 1982). Given the size of the feature, it is unlikely that undercutting by the Teanaway River caused the slide.

Implications. The proximity of the Lookout Mountain slide and the Teanaway River suggests that the slide pushed the river to the west (Figure 13). Such slide-river interactions are relatively common results of mass wasting.

Enroute to Stop 4

Lambert Road to WA 970. *Continue west on Lambert Road to its junction with WA 970. Feel free to head into Cle Elum for a brief restroom stop. We will meet up at Stop 4 at 1:30.*

WA 970 to Teanaway Road. *Turn right onto WA 970. Follow this north and east ~4.2 miles to Teanaway Road. The road crosses a Ronald-age outwash terrace then descends to the Teanaway River floodplain. Notice how the Teanaway is tight against the landslides of Lookout Mountain. After crossing the Teanaway River, ascend a large "debris fan" (i.e., a fan-shaped feature created by a debris flow) from Lookout Mountain. Near the apex of the fan, turn (left) north onto Teanaway Road.*

Teanaway Road to Ballard Hill Road. Follow paved Teanaway Road north approximately 0.3 miles to Ballard Hill Road. The road is on the Teanaway River floodplain.

Ballard Hill Road to Swauk Prairie Road. Turn right and head east on paved Ballard Hill Road for 1.6 miles to Swauk Prairie Road. In doing so, you will ascend the inside face of the Swauk Prairie end moraine. Think of this face as being where the Swauk Prairie ice was as debris tumbled off the end of the ice to form the moraine. Enroute, you will pass by the rebuilt, locally famous Swauk-Teanaway Grange Hall and the Swauk Prairie Cemetery. Ballard Hill Road becomes good gravel at the Swauk-Teanaway Grange Hall.

Swauk Prairie Road to Stop 4. Turn left and proceed north just 0.1 mile on Swauk Prairie Road then bend right and follow it east for ~0.2 mile to the high point on the road. Park along the side of the road. This is Stop 4. ***GPS coordinates are: 47.204238°N & 120.736680°E.***

Stop 4—Swauk Prairie Road

Location. We are located in the northern portion of Swauk Prairie (Figure 20). Teanaway Ridge is to the north, Swauk Creek and Table Mountain lie to the east, and Lookout Mountain is southwest.

Teanaway Formation: Teanaway Ridge, just north of here, is composed of the Teanaway Formation which was first described by Russell (1900) and Smith (1904). The formation consists mainly of basalts (as lava flows and "tephras"—i.e., airfall volcanic ejecta) with some rhyolites and sedimentary rocks (Clayton, 1973).

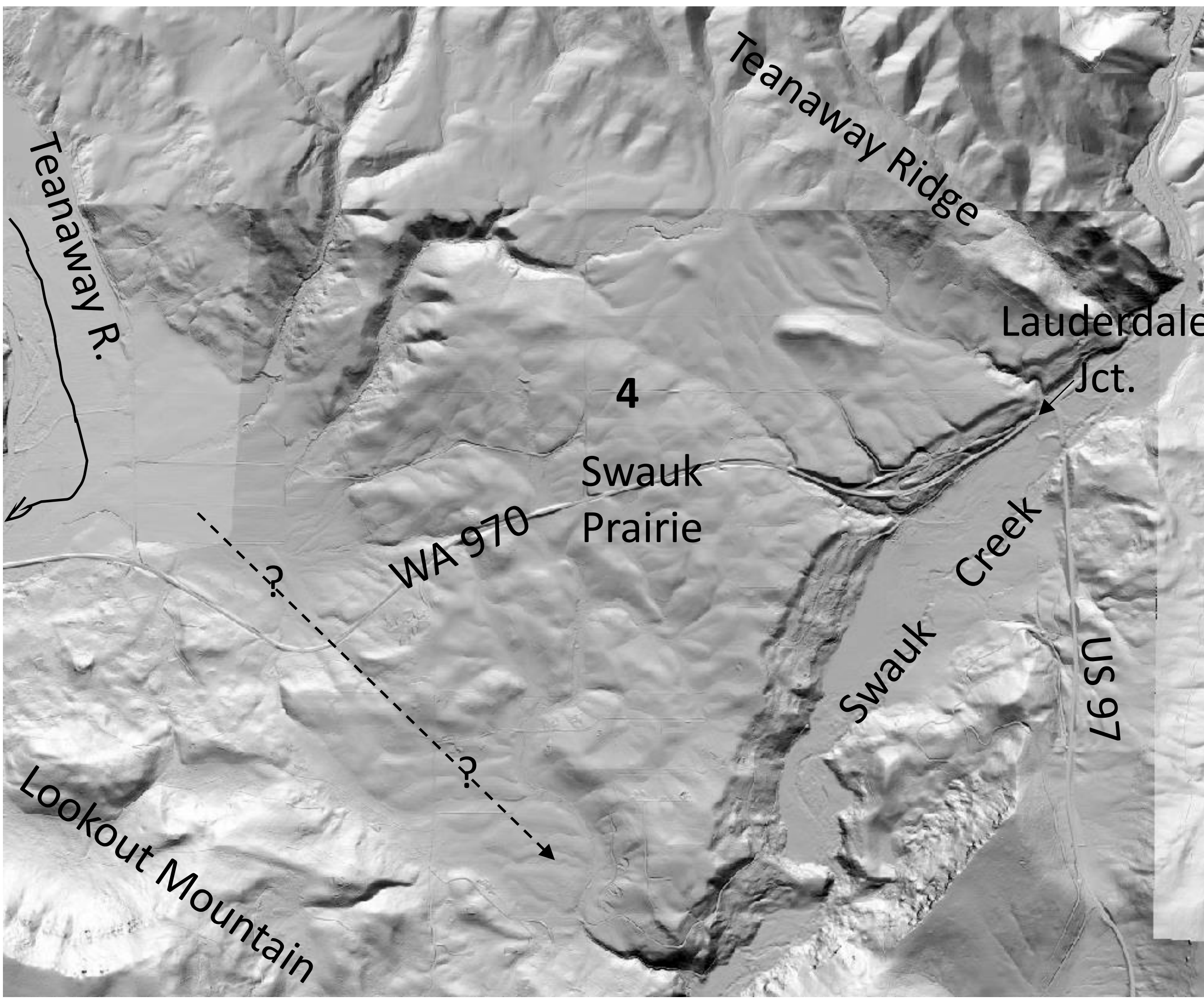


Figure 20. Lidar image of Stop 4 and vicinity. Note Teanaway Ridge, the hummocky terrain of Swauk Prairie, the abrupt distal edge of the Swauk Prairie end moraine, and the ~90^{o} bend in the Teanaway River Valley. Dotted line represents possible path of ancestral Teanaway River to the Swauk Creek canyon. See text for more details. Bold number indicates approximate location of Stop 4. Source: Washington Lidar Portal.

Stop 4—Swauk Prairie Road

Teanaway Formation Dikes & Flows: The Teanaway Formation consists of dikes and flows (Figure 21). "Dikes" form as magma rises and stretches Earth's crust ultimately forming fissures that fill with magma. Some of the Teanaway basalt dikes may have been "feeder dikes′ to a variety of volcano types (e.g., shield volcano, cinder cone, and composite cone) in the area. Unfortunately, the volcanic landforms are so old that little remains of their original morphologies. Flows may originate at fissures that later become dikes when magma cools.

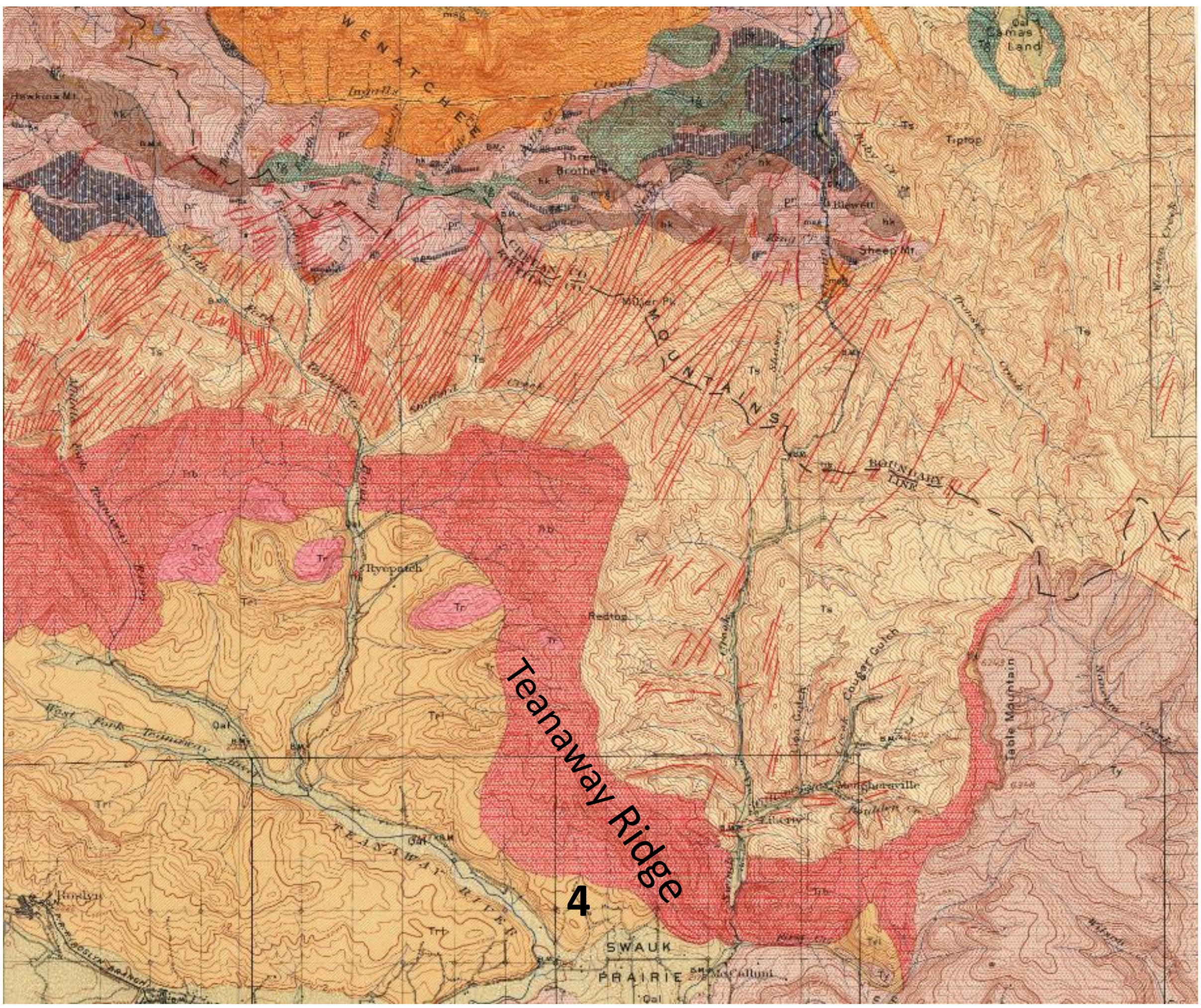


Figure 21. Teanaway Formation flows (broad area of red) and dikes (red lines) in the Eastern Cascades. Note the location of Teanaway Ridge. Bold number indicates approximate location of Stop 4. Source: Smith (1904).

Stop 4—Swauk Prairie Road

Teanaway Formation Composition. Composition of the formation is mainly basalt with some rhyolite (Clayton, 1973). Of the basalts, most occurs as "tuffs" (i.e., welded volcanic ash), "lapilli tuffs" (i.e., a mix of welded ash and coarser airfall tephra), and "tuff breccias" (i.e., a mix of welded ash and angular fragments). Taken as a whole, the Teanaway Formation ranges from ~2600-4000 feet thick (Clayton, 1973).

Teanaway Formation Distribution. The distribution of Teanaway Formation in the area ranges from here westward to Lake Kachess near I-90 (Figure 22). It composes several of the prominent summits in the area including Easton Ridge, Hex Mountain, Yellow Hill, Teanaway Butte, and Red Top Mountain.

Age of the Teanaway Formation. Rhyolite at the base of the Teanaway Formation dates to about 49.3 Ma (Eddy and others, 2017). Dates on the overlying Chumstick Formation to the north suggest that the Teanaway Formation was deposited over less than 200,000 years (Eddy and others, 2017). Think about that—a widespread geologic formation ~2600-4000 ft thick that was deposited in less than 200,000 years. This is impressive!

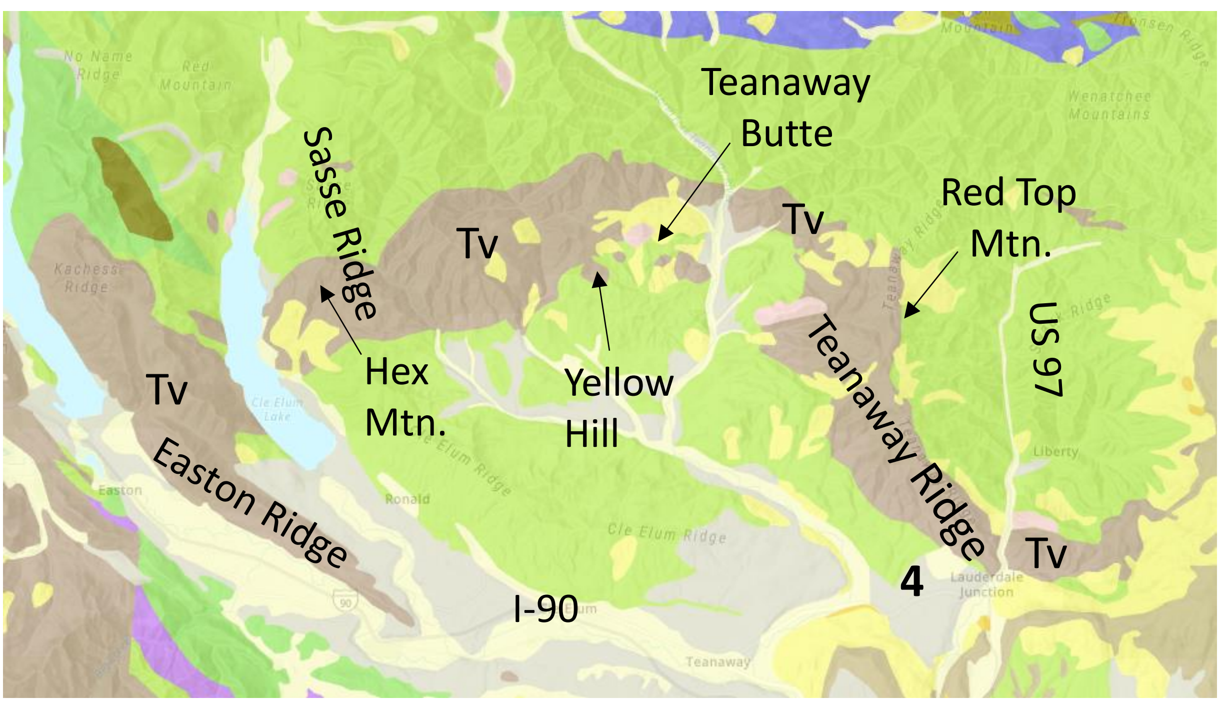


Figure 22. The extent of Teanaway Formation (Tv) in the vicinity of US 97 and I-90 in central Washington. Note the location of Teanaway Ridge. Bold number indicates location of Stop 4. Source: Washington Geologic Information Portal.

Stop 4—Swauk Prairie Road

Tectonic Setting of the Teanaway Formation. Because the Teanaway Formation includes two very different types of volcanic rocks (i.e., basalt and rhyolite), it is said to have "bimodal volcanism" (Eddy & others, 2017). Other such bimodal volcanics with similar Eocene ages (between ~50-48 Ma) are found throughout the Cascade Range (Figure 23) The volcanic activity in each of these is significant because it occurred at about the same time or followed the accretion of Siletzia, and preceded the onset of the Cascade arc (Kant & others, 2018). The breakoff of the Farallon Plate during subduction appears to be the cause of the belt of 50-48 Ma igneous rocks in Washington including the Teanaway Formation (Kant & others, 2018) (Figure 24); therefore, these 50-48 Ma volcanics are sometimes referred to as "slab breakoff magmas".

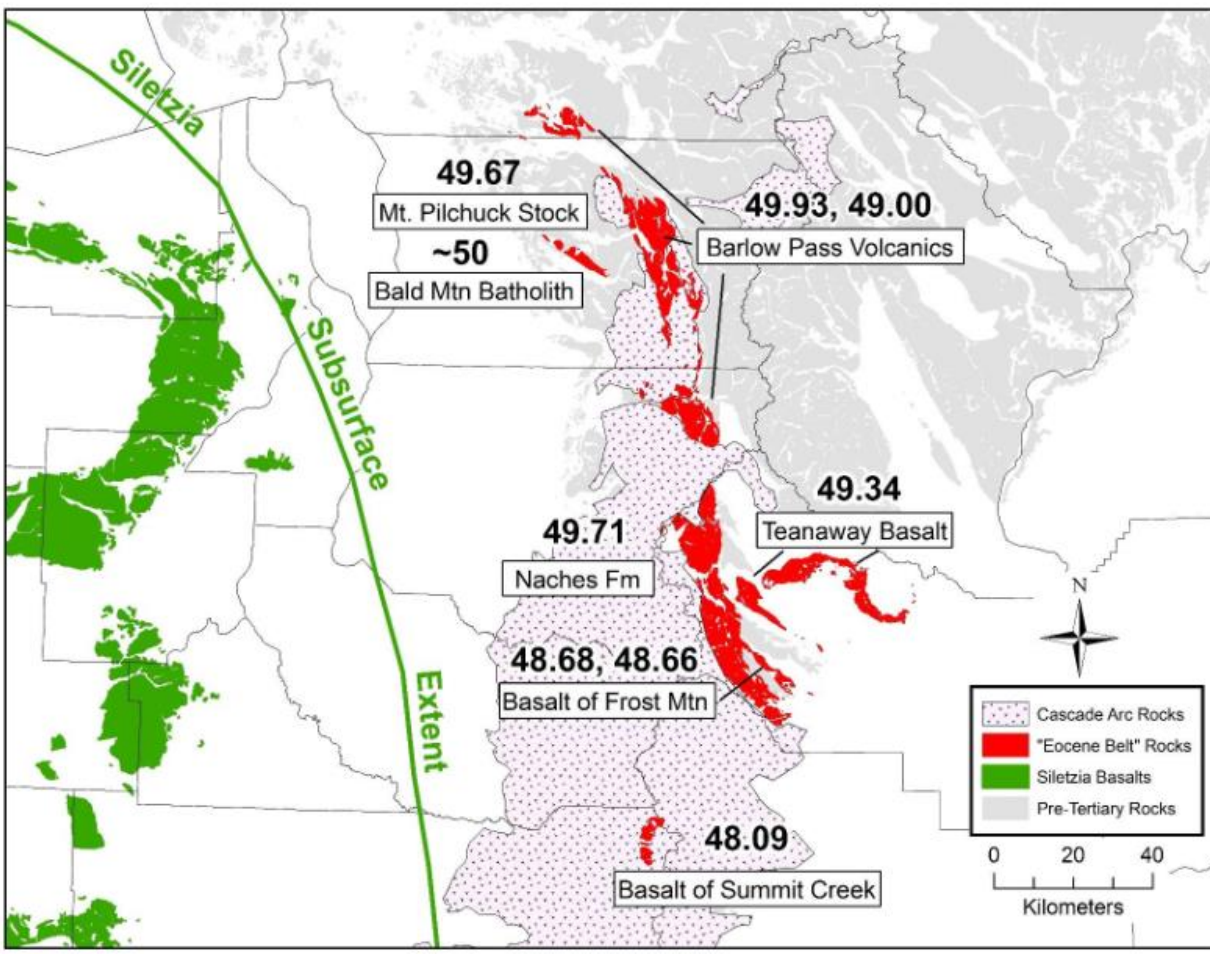


Figure 23. Eocene Belt rocks (i.e., slab breakoff magmas) of the Washington Cascades. Unit TB represents the Teanaway Formation. Source: Jeff Tepper, written communication, 3 March 2025.

Stop 4—Swauk Prairie Road

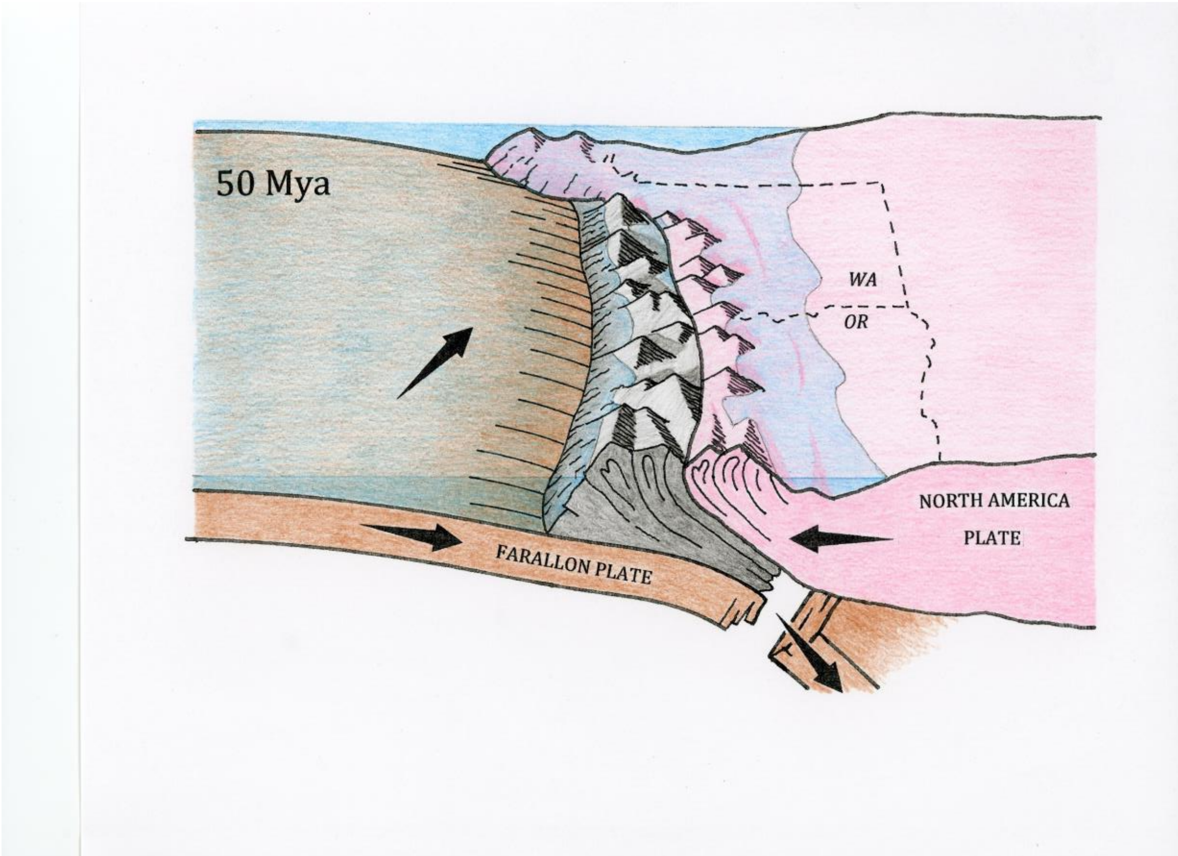


Figure 24. Breakoff of the subducting Farallon Plate thought to be associated with the formation of 50-48 Ma magmas in present-day Washington and Oregon. Source: Ken Clark, written permission, 28 February 2025.

Glaciers & Climate. At Stop 2, I noted that large valley glaciers moved eastward from the Cascade Crest. More specifically, these glaciers originated in cirques above the valleys now occupied by lakes Cle Elum, Kachess, and Keechelus. Why didn't large valley glaciers originate in the nearby Teanaway and Swauk creek valleys? The answer lies in the climate requirements of glaciers. Large glaciers require low temperatures <u>and</u> ample precipitation. With elevations ranging to over 7000 feet in the Teanaway River Watershed and over 6000 feet in the Swauk Creek Watershed, temperatures should have been sufficiently low to form glaciers. However, the generally south aspect of both watersheds would have diminished the impacts of the higher elevations. Further, the location east of the Cascade Crest and the resulting low precipitation also diminished the potential for glaciation in the watershed.

Stop 4—Swauk Prairie Road

Glaciers & Climate (continued)… A good modern analogy of the decline in precipitation (esp. snow) east of the Cascade crest can be seen in data from three US Department of Agriculture SNOTEL sites. Stampede Pass (near Snoqualmie Pass) receives about 85 inches/yr, Sasse Ridge (just east of upper Lake Cle Elum) gets about 55 inches/yr, and Blewett Pass receives about 32 inches/yr. Sasse Ridge is the most representative site for the upper western Teanaway while Blewett Pass is more representative of the upper eastern portions of the watershed as well as the Swauk Watershed. Each typically receives much less precipitation than Stampede Pass.

Glaciers in the Teanaway: While large valley glaciers did not form in the Teanaway River Valley, the Lookout Mountain Ranch- and Swauk Prairie-age glaciers did spill into the lower Teanaway from the Cle Elum drainage (Porter, 1976). The Swauk Prairie glacier split around Lookout Mountain reaching within 100 feet of its summit. This suggests that the glacier was over 1200 feet thick here near its terminus! At its maximum extent, >600,000 yr BP, the Swauk Prairie glacier was >40 miles long.

Swauk Prairie End Moraines, Time & Loess. The high surface we are standing on is a Swauk Prairie end moraine. End moraines, like their name implies, are ridge-like features that form at the end (i.e., terminus or snout) of a glacier (Figure 11). They typically form from debris falling off the edge of the ice therefore giving end moraine a "hummocky" appearance. End moraines indicate that a glacier occupied an area sufficiently long for such deposits to accumulate. The end moraines here are not classic, textbook features for several reasons. First, Swauk Prairie is not composed of one end moraine; rather, it consists of perhaps as many as six very, very subtle end moraines, each of which arcs across the area (Porter, 1976) and indicates a stillstand during ice retreat. Second, the Swauk Prairie moraines are not textbook examples of such features because they are old. These features are Middle Pleistocene in age, likely forming more than 600,000 years before present (Swanson and Porter, 1997). Because of their age, they have had much time to weather, erode, and be blanketed by loess. According to Natural Resource Conservation Service soil series descriptions for the area, "loess" (i.e., windblown silt, clay, and fine sand) thicknesses range from 2 to 5 feet atop glacial till. Each of the two dominant soils of Swauk Prairie—Qualla and Swauk—is characterized by an accumulation of clay at depth. This is good supporting evidence of the age of these soils, hence the age of the moraines. It was this loess that allowed these lands to be extensively farmed over time. What is the source of the loess? Did it come from: 1) nearby Upper Yakima River outwash plains; 2) Okanogan Lobe of the Cordilleran Icesheet outwash plain; or 3) Ice Age flood slackwater deposits in the Pasco Basin? At this point, we don't know.

Stop 4—Swauk Prairie Road

Glaciers & Ice Marginal Lakes: Lakes were likely present in the lower Teanaway River and Swauk Creek valleys during earlier glaciations (Porter, 1969, 1976; Tabor & others, 1982). Blue clays, "rhythmites" (i.e., alternating fine and coarser textured sediments), and "dropstones" (i.e., stones within otherwise finer sediments) suggest that lakes formed adjacent to glacial ice in the lower Teanaway River Valley. One of these lakes may have been sufficiently deep to drain across the Swauk Prairie moraine into Swauk Creek. In the Swauk Creek valley, laminated, blue-gray clay near Lauderdale Junction (Figure 20) has been interpreted as glacial lake sediment deposited in an ice marginal lake (Tom Lyon, personal communication).

Swauk Creek-Teanaway River Interactions: The "underfit" nature of Swauk Creek in its lower valley suggests that it was much larger in previous times. The Teanaway River bends sharply from its NW to SE path to a more NE to SW path near its mouth (Figure 20). These two pieces of evidence suggest that, prior to the Swauk Prairie glaciation, the Teanaway River flowed into Swauk Creek, and that the subsequent deposition of the Swauk Prairie end moraine diverted the Teanaway to its present course.

Enroute to Stop 5

Swauk Prairie Road to WA 970. Follow Swauk Prairie Road for about 1.4 miles southeast to WA 970. This route descends from the top of the end moraine into the Swauk Creek Valley.

WA 970 to US 97. Turn left onto US 97 and head northeast about 0.6 miles to the junction with US 97.

US 97 to Stop 5. Turn right onto US 97 head south for about 2.7 miles to Stop 5. In that short distance, you will cross Swauk Creek and leave the Swauk Creek Valley, pass through the toe of a large landslide that originated in the uplands to the east, pass by the iconic Dunford barn, and cross the head of Horse Canyon. Park in the wide gravel area on the right (west) side of the road. ***GPS coordinates: 47.165915°N & 120.705393°W.***

Stop 5: US 97 Horse Canyon Overlook

Location. We are near the lower edge of the Swauk Creek Watershed, above Horse Canyon (Figure 25). Swauk Creek, which we crossed near Lauderdale Junction, is about 1.5 north of us, just beyond the near ridge in the foreground. Teanaway Ridge lies to the northwest. Table Mountain lies to the northeast, and the Kittitas Basin is to the south. Also visible are some of the higher peaks of the upper Teanaway. The summits of many of these peaks are supported by ~49 Ma Teanaway Formation dikes.

Columbia River Basalts. We are on and immediately surrounded by mid-*Miocene* Grande Ronde Basalts of the Columbia River Basalts. These basalts originated from *fissure eruptions* in southeastern Washington, northeastern Oregon, and western Idaho. They are exposed in the roadcut across US 97 to the east.

Glaciers. Glacial evidence was mapped in Horse Canyon and named the Thorp "Drift" (i.e., catchall term for glacial deposit) (Porter, 1976). This was subsequently renamed the Lookout Mountain Ranch Drift (Waitt, 1979). The evidence Porter (1976) cites is what we look for as geomorphologists—morphological (i.e., a possible lateral moraine landform) and stratigraphic (i.e., a well-weathered mix of rocks overtopped by a well-developed soil). Unlike some other glacial drifts in the area, these deposits lack a corresponding glacial outwash.

Horse Canyon Enigma. Long ago, one of my geomorphic mentors, Dr. Martin Kaatz of CWU's Geography Department, alerted me to the question of Horse Canyon's origins. Horse Canyon's size suggests that a large amount of liquid water or ice flowed through this in the past (Figures 25 & 26). However, it heads at a low divide through which US 97 passes—i.e., there is no high headwater area and this is odd. At that pass, water flows south into Horse Canyon and north into Swauk Creek proper (Figure 27). So how might Horse Canyon have originated?

- Some have argued that Horse Canyon is the abandoned valley of Swauk Creek (Smith, 1904). According to this theory, this earlier channel of Swauk Creek was abandoned when the Teanaway River "captured" Swauk Creek taking it westward through its modern-day canyon to join the Yakima River. Stream captures may take place when the capturing stream has a steeper gradient and "headwardly erodes" through the drainage divide of another stream. This is difficult to envision given the position of Horse Canyon's head. Did the capturing stream remove Horse Canyon headwaters to the north? And how does this canyon relate to Green Canyon to the east which may have served as a glacial outwash corridor (Sadowski & others (2020).

Stop 1—US 97 Horse Canyon Overlook

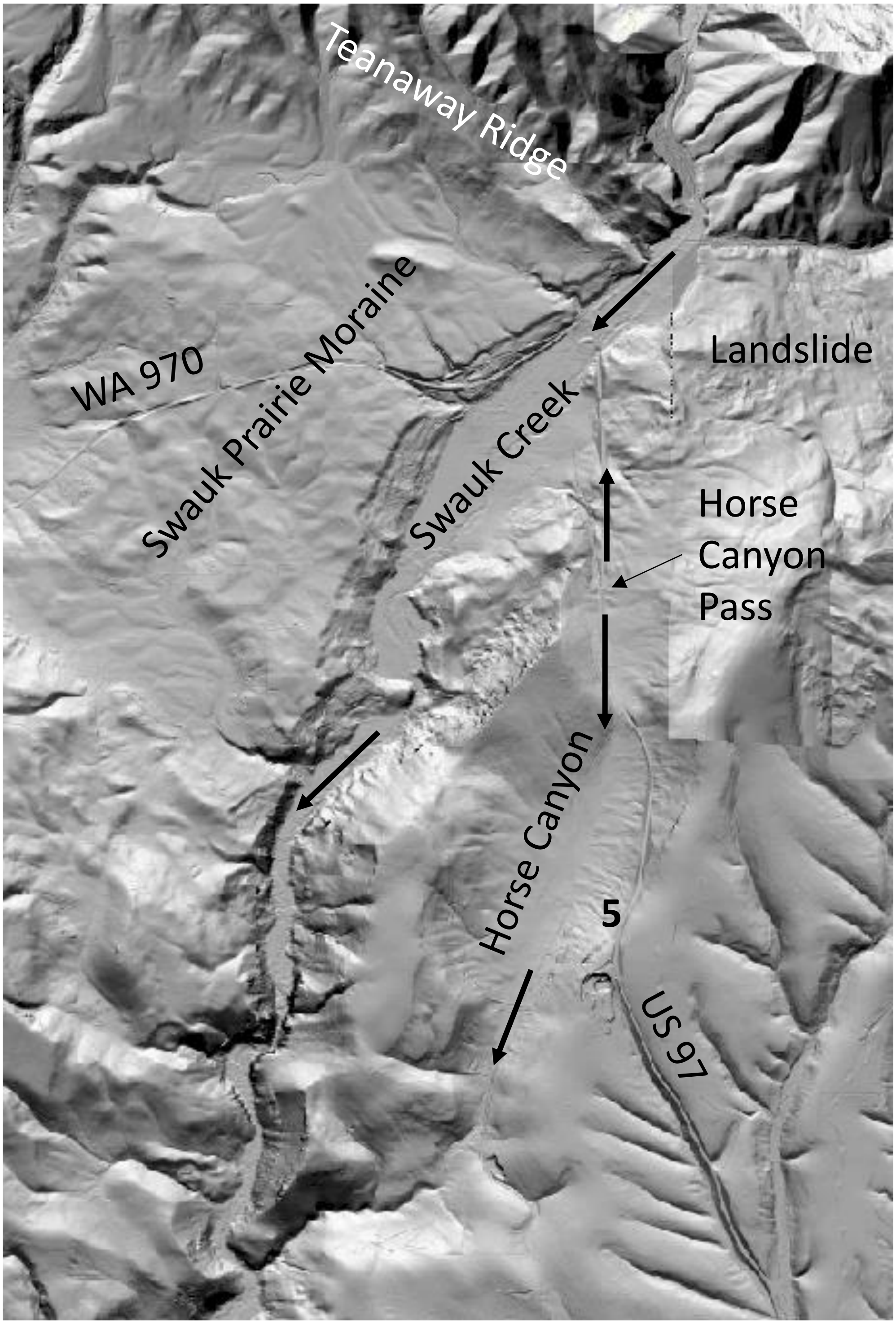


Figure 25. Vertical overhead lidar image of Horse Canyon and vicinity. Bold arrows indicate water flow directions. Bold number indicates approximate location of Stop 5. Source: Washington Lidar Portal.

Stop 1—US 97 Horse Canyon Overlook

- The broad, U-shaped valley also suggests past glaciation (Porter, 1965) (Figures 25 & 26). Porter (1976) noted the presence of a possible lateral moraine on the west side of Horse Canyon to support this theory. Unfortunately, I have not been able to locate this moraine on 7.5' topographic maps, Google Earth Pro, or lidar imagery. If present, this would be the Lookout Mountain Ranch Glaciation. Again, this is a dilemma considering the pass.
- Given the amount of mass wasting that is present on the edges of the Columbia River Basalts nearby (Figure 25), could Horse Canyon have formed from a very large landslide moving from east to west? In this scenario, the slide block would be the ridge to the west of Horse Canyon and the canyon is the sag behind the block. Think in terms of a larger version of the Lookout Mountain landslide. If this is the case, where are the hummocky deposits that often characterize the toes of large slides? And what created the rounded sides of the valley?

At this point, we don't have a good answer to this question.

Figure 26. Oblique aerial view of U-shaped Horse Canyon looking north into the heart of the Swauk Watershed. Bold number indicates the approximate location of Stop 5. Arrows indicate directions of water flow. Source: Google Earth Pro (9/25/2011 image).

Wrapping Up

Summary. Here, on the margins of the Eastern Cascades, we have seen a variety of geologic formations that are the result of different tectonic situations over the past 50+ Ma. We have also seen the impacts of weather and climate as well as tectonics on the landforms of the area. This landform evidence spans the past >600 Ka. And we have seen the impacts of the underlying geologic formations and landforms on human settlement in the area.

Thanks. Thanks for participating today. And thank you for your support of the Ellensburg chapter of the Ice Age Floods Institute. These trips don't happen without your continued interest and support. Feel free to contact me at lillquis@cwu.edu or (509) 963 1184 if you have further questions/comments. I hope to see you on the next trip in mid-June 2025.

***To get back to Ellensburg**: Continue south on US 97 back to Ellensburg's West Interchange. The route follows Dry Creek which typically only flows a few weeks a year as a result of lowland snow runoff and perhaps a severe thunderstorm. Dry Creek flows between two basin fill remnants of Ellensburg Formation capped by the Thorp Gravels.*

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