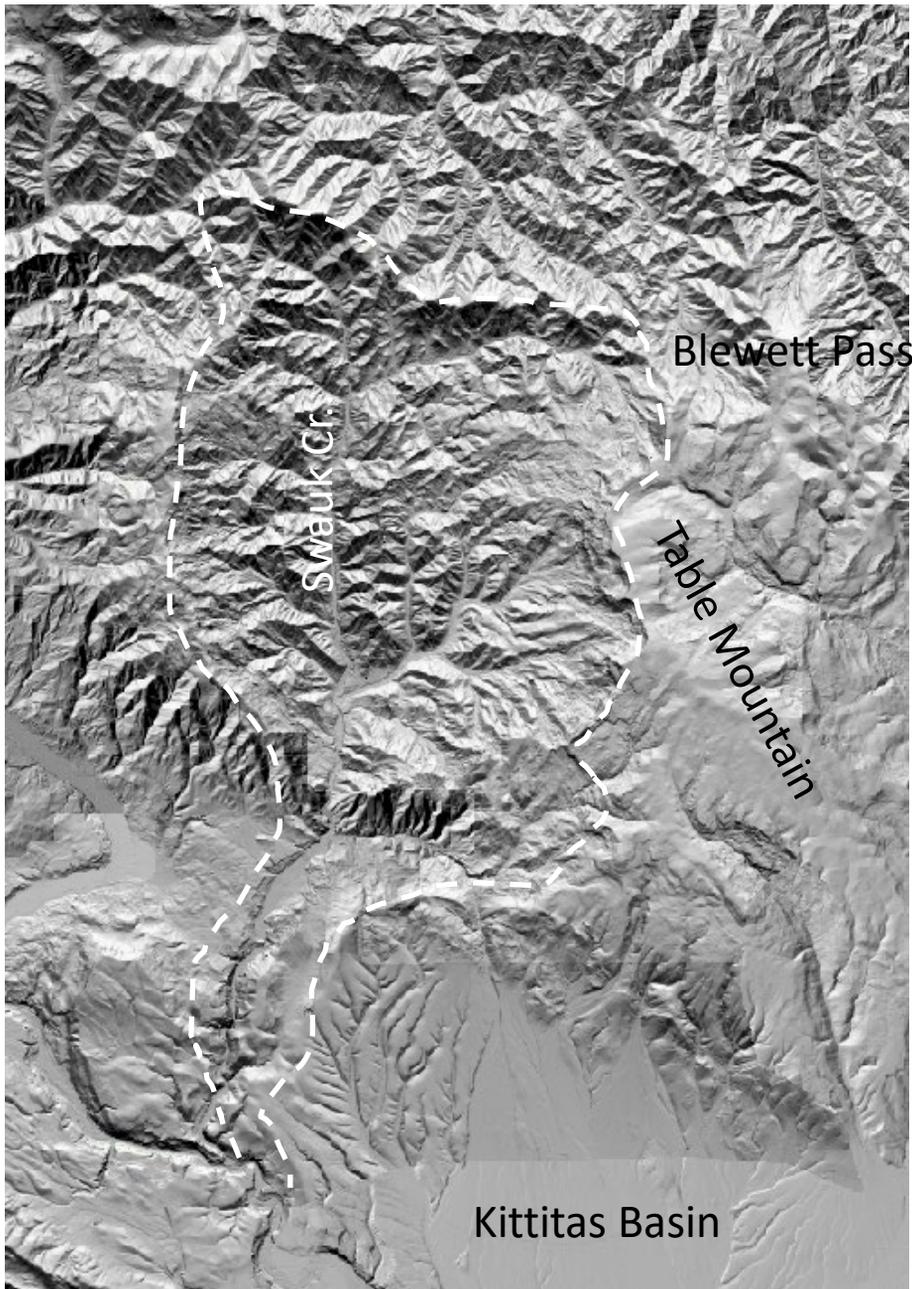


# ***Landforms & Landscapes of the Swauk Watershed***



**Field Trip Leader:**

**Karl Lillquist, Geography Department, CWU**

**October 2022**

# Introduction

The Swauk Watershed is, at first glance, a relatively non-descript watershed through which US 97 crosses the southern part of the Wenatchee Range between Ellensburg and the Wenatchee River Valley. At deeper inspection, it is a basin that has been impacted by a variety of landform-shaping factors and processes over time. These include bedrock, climate, volcanism, tectonics, weathering, landsliding and rockfall, streams, and glaciers. Human activity in the form of railroad and highway construction, and mining activity, has played a major role in shaping valley floors. Join us as we explore the impacts of these factors and processes on landforms and landscapes of the eastern portion of the Swauk Watershed.

## Tentative Schedule

10:00am Arrive at Stop 1—Horse Canyon Overlook  
10:45 Depart  
11:15 Arrive at Stop 2—Swauk Creek-Hurley Creek junction  
12:00pm Depart  
12:30 Arrive at Stop 3—Upper Swauk Creek1  
1:30 Depart  
2:00 Arrive at Stop 4—Middle Lion Gulch  
2:45 Depart  
3:00 Arrive at Stop 5—Upper Durst Creek  
3:45 Depart

# Stop 1: Horse Canyon Overlook

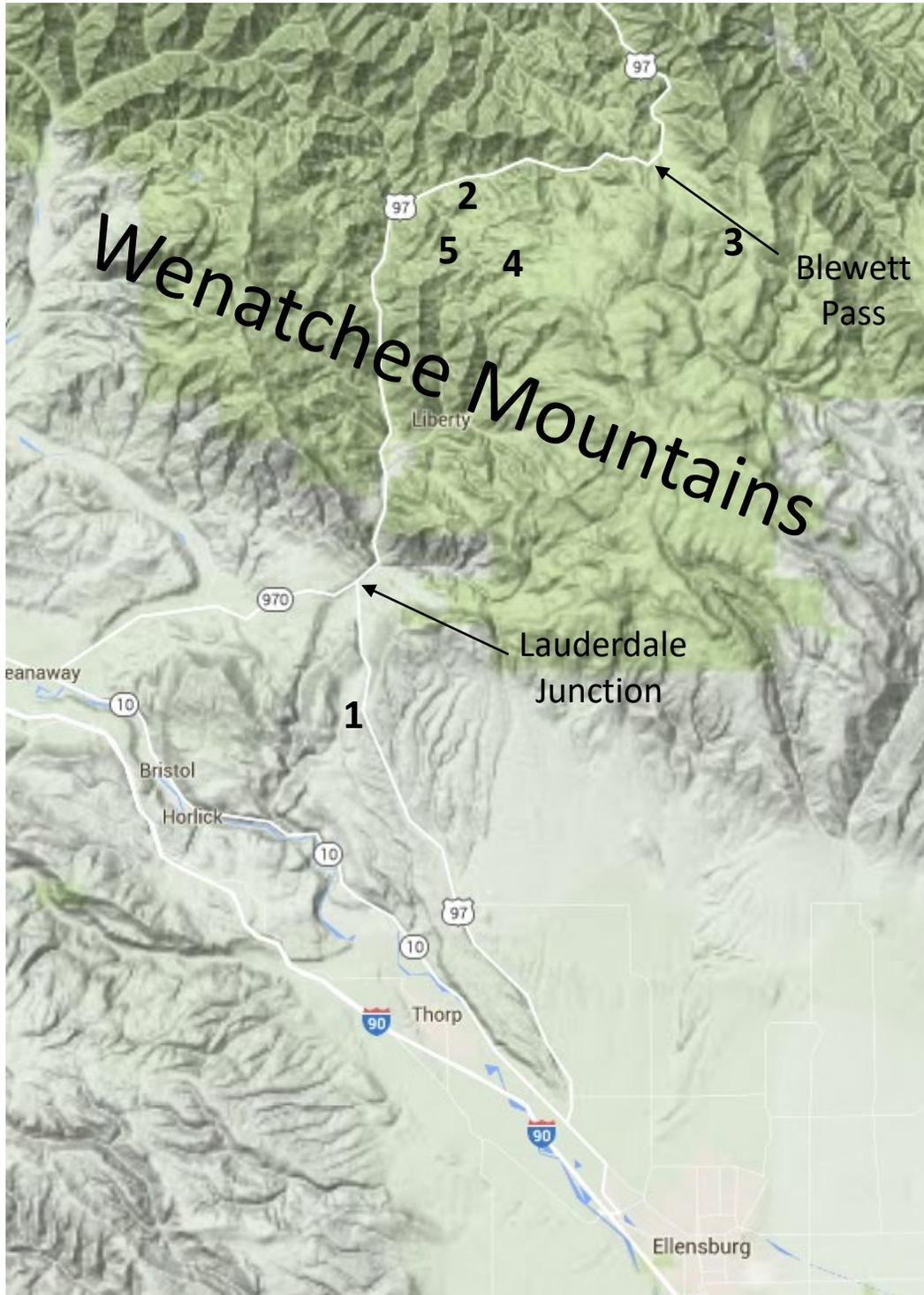
**Getting our bearings.** We are located at a wide pullout along US 97 overlooking Horse Canyon. Our GPS coordinates are 47.166035° N and 120.705224° W. We are standing near the lower edge of the Swauk Creek Watershed, above Horse Canyon (Figure 1). Swauk Creek, which we will cross as we near Lauderdale Junction, is about 1.5 west 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.

**Swauk Creek Watershed.** The Swauk Creek Watershed (or just Swauk Watershed) has its origins in the uplands to the north—Teanaway Ridge, Wenatchee Ridge, and Table Mountain. US 97 follows Swauk Creek to its headwaters very near Blewett Pass at the junction between Wenatchee Ridge and Table Mountain. Swauk Creek flows into the Yakima River west of Thorp.

**Geology.** We will see four key geologic units today—the *igneous* Columbia River Basalts, *sedimentary* Swauk Formation and Roslyn Formation, and igneous Teanaway Formation (Figure 2). These units play a huge role in the character of landforms and landscapes in the watershed. We are on and immediately surrounded by mid-*Miocene* Columbia River Basalts. These basalts originated from *fissure eruptions* in southeastern Washington, northeastern Oregon, and western Idaho. They are exposed in the roadcut to our east. The high elevations in the northern mid-ground consist of volcanic rocks of the early *Eocene* Teanaway Formation. They occur as flows and *dikes* (i.e., fracture fillings). The early Eocene sedimentary Swauk Formation forms much of the watershed north of Lauderdale Junction.

**Glaciation.** This is the only stop where we will be near glaciated terrain. Let this sink in a bit—i.e., we will be travelling in the Wenatchee Mountains (an offshoot of the Cascade Range) throughout the day yet will not be in glaciated terrain. This means that good evidence for glaciation in the higher portions of the watershed has not been found. However, a large alpine glacier did move down the Upper Yakima River Watershed several times in the Pleistocene. In the Middle Pleistocene (approximately 500,000 years ago) (Swanson and Porter, 1997), a Yakima River Valley glacier terminated just west of Lauderdale Junction and Swauk Creek (Figure 3). This has been termed the Swauk Prairie member or phase of the Kittitas Drift (Porter, 1976; Waitt, 1979). This terminal zone is marked by a prominent *end moraine* over which WA 970 passes. Further, glacial evidence was mapped in Horse Canyon and named the Thorp Drift (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*.

# Stop 1—Horse Canyon Overlook



**Figure 1. General topography of the Swauk Watershed. Bold numbers indicate approximate locations of field trip stops. Source: Google Maps.**



# Stop 1: Horse Canyon Overlook

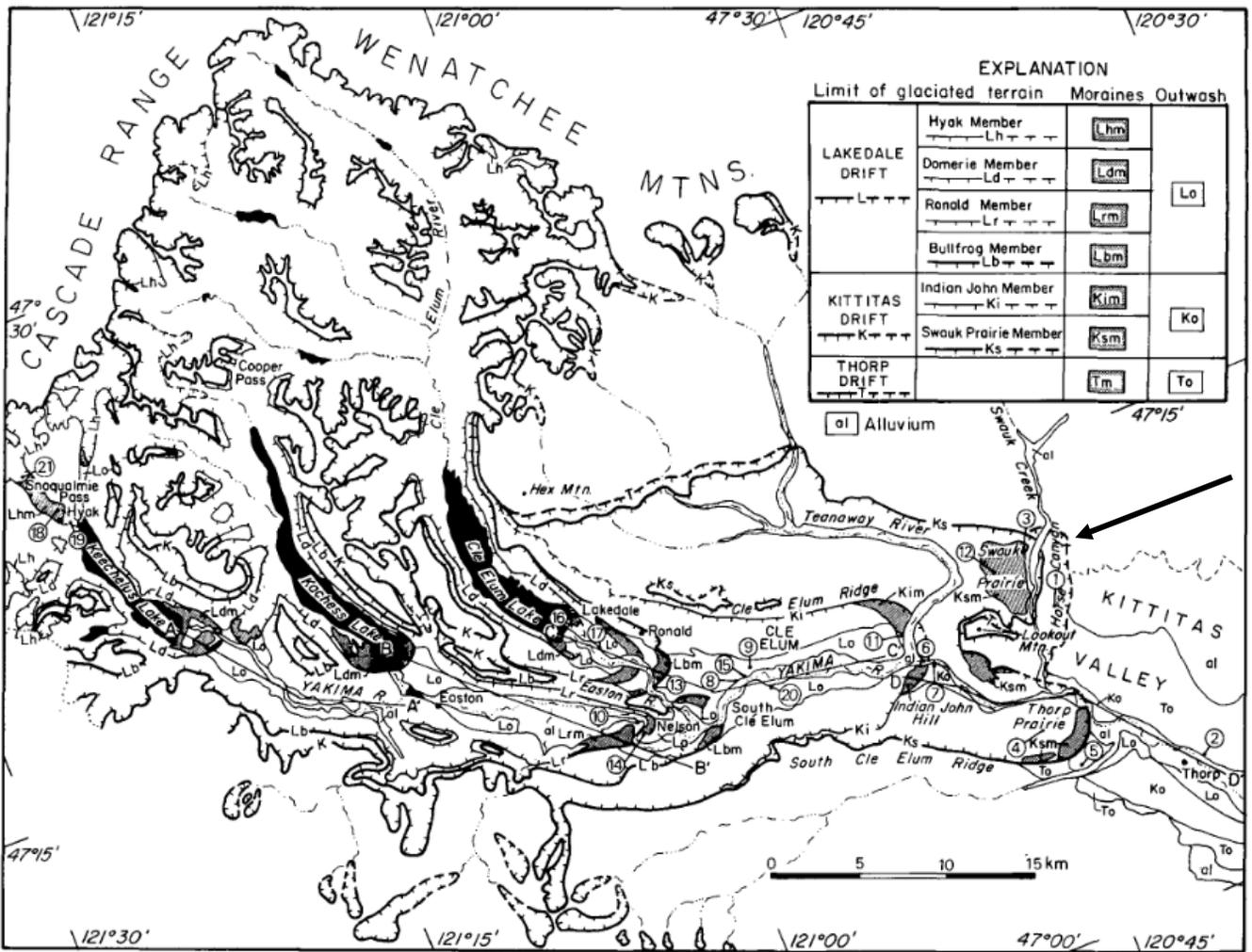


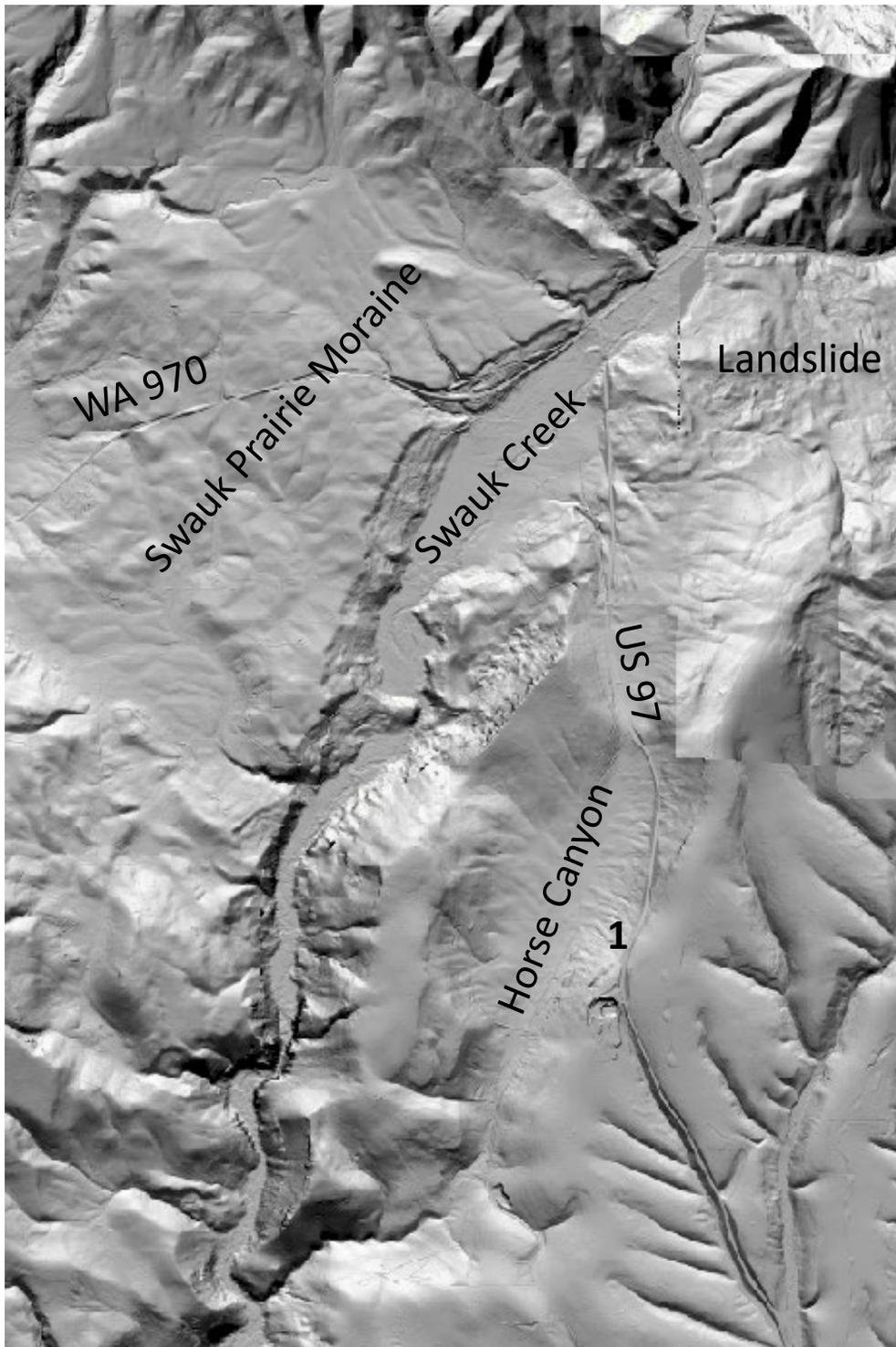
Figure 3. Map of the extent of different glaciations in the Upper Yakima River Watershed. Note arrowed Horse Canyon near the eastern edge of map. Source: Porter (1976, p. 62).

# Stop 1—Horse Canyon Overlook

**Horse Canyon Enigma.** Long ago, one of my geomorphic mentors, Marty Kaatz, 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 at one point (Figures 4 & 5). However, it heads at a low divide through which US 97 passes—i.e., there is no high headwater area and this is odd. So how might Horse Canyon have originated?

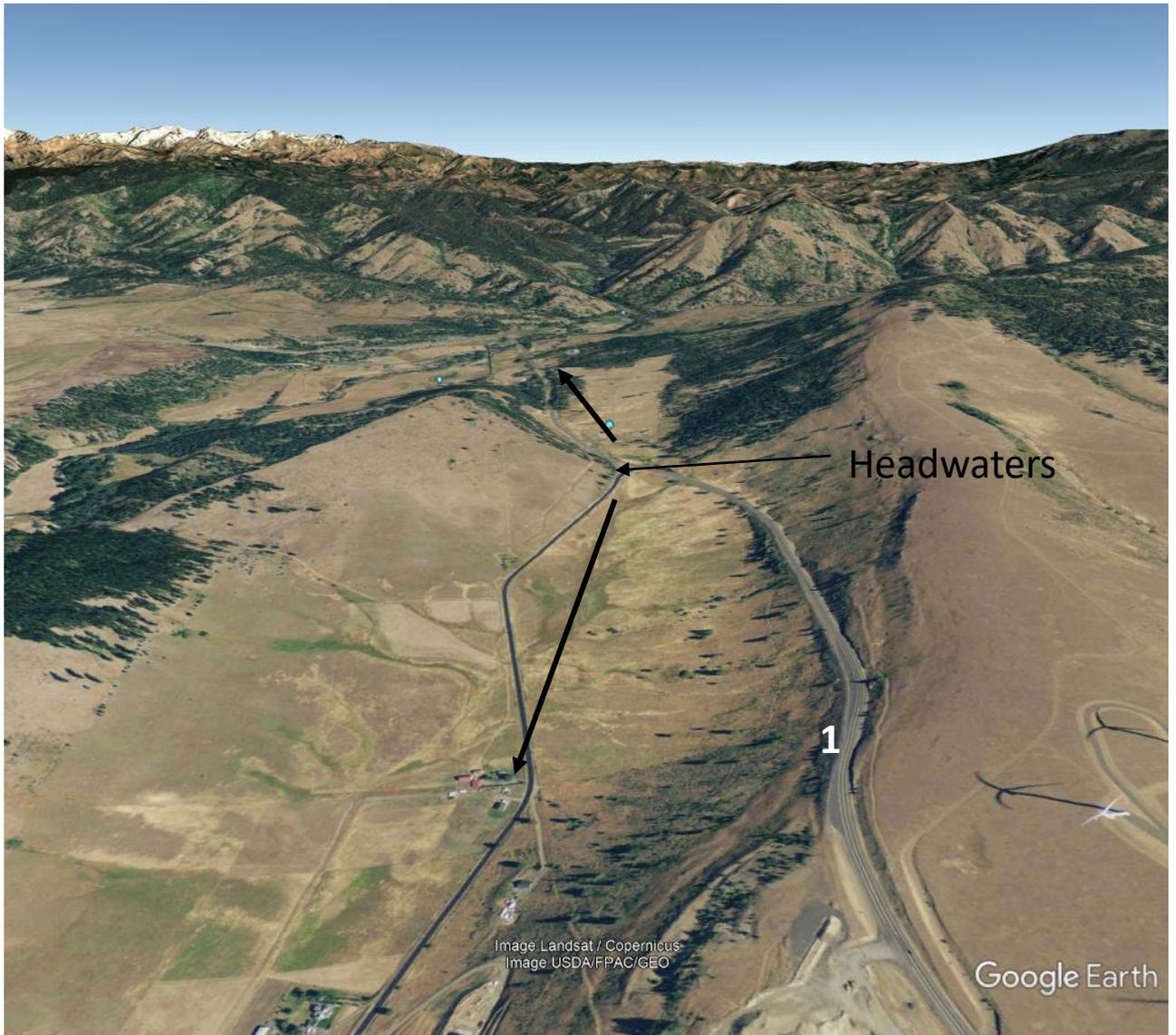
- 1) Some have argued that Horse Canyon is the abandoned valley of Swauk Creek (Smith, 1904). According to this theory, this earlier channel of Swauk Creek was abandoned when the Teanaway River *captured* Swauk Creek taking it westward through its modern-day canyon to join the Yakima River. Stream captures 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 as the head of the floor of Horse Canyon is at ~2,500 feet elevation. The current floor of Swauk Creek about 2 miles north is at about 2,200 feet.
- 2) The broad, U-shaped valley also suggests past glaciation (Porter, 1965) (Figures 5 & 6). 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.
- 3) Given the amount of mass wasting that is present on the edges of the Columbia River Basalts (Figure 4), could Horse Canyon have formed from a large landslide moving from east to west? In this scenario, the slide block would be the ridge to the west of Horse Canyon. This seems less likely as the LIDAR image does not show the hummocky deposits so characteristic of mass wasted terrain.

# Stop 1—Horse Canyon Overlook



**Figure 4. Vertical overhead Lidar image of Horse Canyon and vicinity. Bold number indicates approximate location of Stop 1. Source: Washington Lidar Portal (<https://lidarportal.dnr.wa.gov/>).**

# Stop 1—Horse Canyon Overlook



**Figure 5. Oblique view of U-shaped Horse Canyon looking north into the heart of the Swauk Watershed. Bold number indicates the approximate location of Stop 1. Arrows indicate direction of water flow. Source: Google Earth Pro (9/25/2011 image).**

# Stop 1—Horse Canyon Overlook

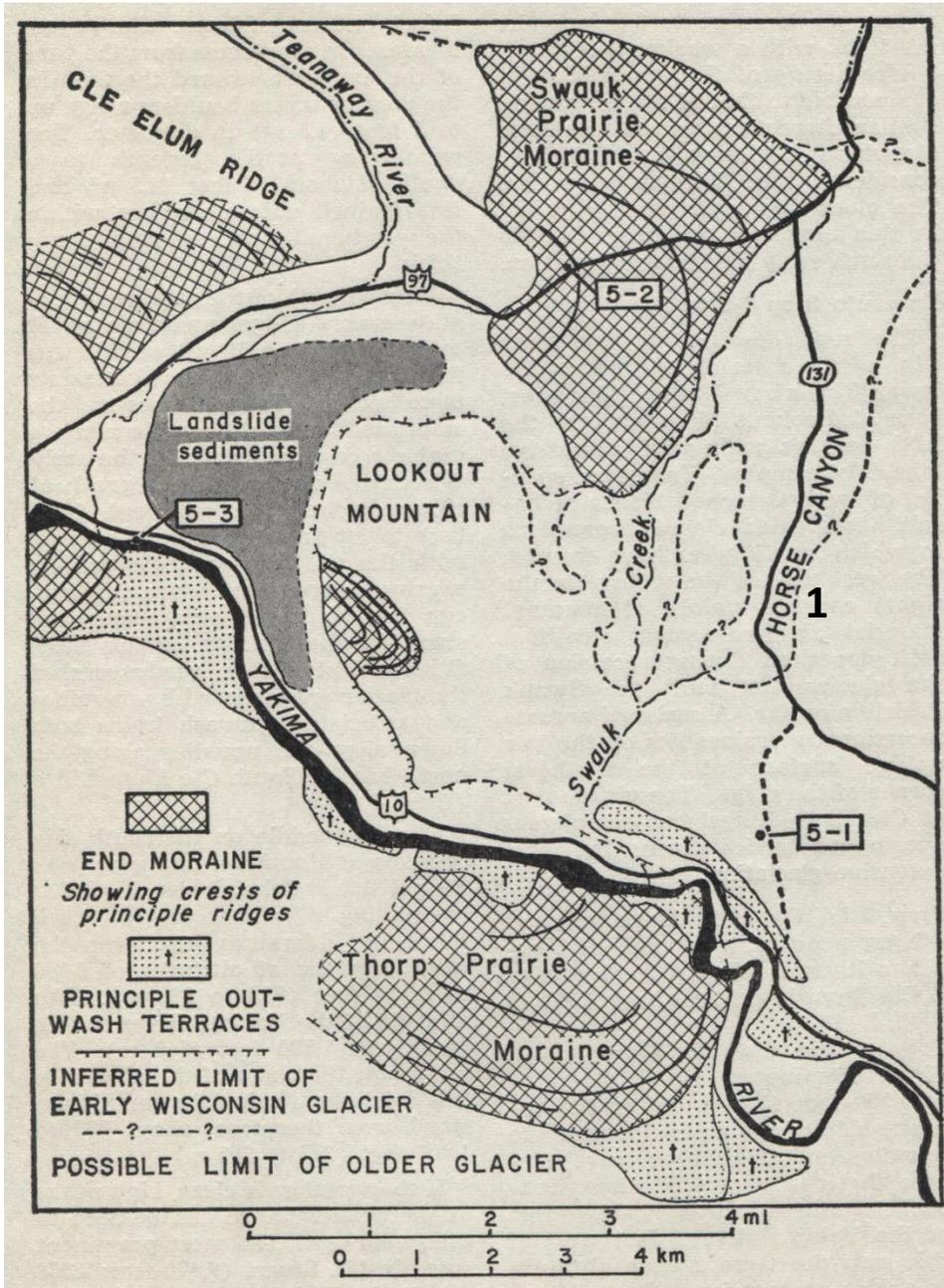


Figure 6. Evidence of Upper Yakima River Valley alpine glaciation in the vicinity of Swauk Creek. Note the possible limit of older glaciation (Thorp of Porter and Lookout Mountain Ranch of Waitt) in Horse Canyon. Bold number indicates the approximate location of Stop 1. Source: Porter (1965, p. 37).

# Horse Canyon Overlook to Swauk Creek – Hurley Creek Junction

**From here.** Continue north on US 97 ~2.5 miles to the junction with WA 970. Turn right (east) at this junction and continue on US 97 ~9.5 miles to NF-9711 at the junction of Swauk Creek and Hurley Creek. Turn right onto NF-9711, and continue for about 0.25 miles. Park near the sharp bend in the road. This is Stop 2.

**Geology.** Watch for red-brown bedrock of the Teanaway Formation in the form of flows near Lauderdale Junction and as dikes further north. Light colored facies of the sedimentary Swauk Formation surround the dikes.

**Dredge Mining.** Gold mining and logging have long been land uses in the Wenatchee Mountains. On the south side of the range, mining was centered in the Liberty area. *Placer* mining of Swauk Watershed stream sediments began in about 1874 (UW Geology Department Staff, 1963). You can see spoil heaps of floating dredge-based, placer mining of Swauk Creek sediments along the west side of US 97 between Lauderdale Junction and the Liberty Café (Figures 7 & 8). It is unclear when this area was dredged. Dredging occurred upstream near the junction of Williams and Swauk creeks (where the Liberty road splits off US 97) from about 1922-23 and another operated near the junction of Deer Gulch and Swauk Creek from 1926-1929 (UW Geology Department Staff, 1963). This mining process, which is highly destructive to floodplains, water quality, and fish, still occurs today, albeit on a much smaller scale through the use of small, suction dredges. *Lode* (i.e., hard rock) mining began here in 1881 and still occurs here as well. For more information on Swauk Watershed mining, past and present, see Woodhouse and others (2002).

**Downhill Skiing, Swauk Ski Bowl, and Mineral Springs Resort.** A ski area--the Swauk Ski Bowl--operated just north of the present-day Swauk Campground (~1 mile upvalley from Stop 2) from 1946 to 1953 (Cle Elum Ranger District, 1997). It used a lodge that had been built by the Works Progress Administration as well as civic groups and the U.S. Forest Service in 1940. Following the closure of the ski area, schools used the facility until the late 1950's. In the early 1960's it was sold and moved in three sections to Mineral Springs where it forms part of the present-day lodge. We will pass by this lodge enroute to Stop 2.

# Horse Canyon Overlook to Swauk Creek – Hurley Creek Junction

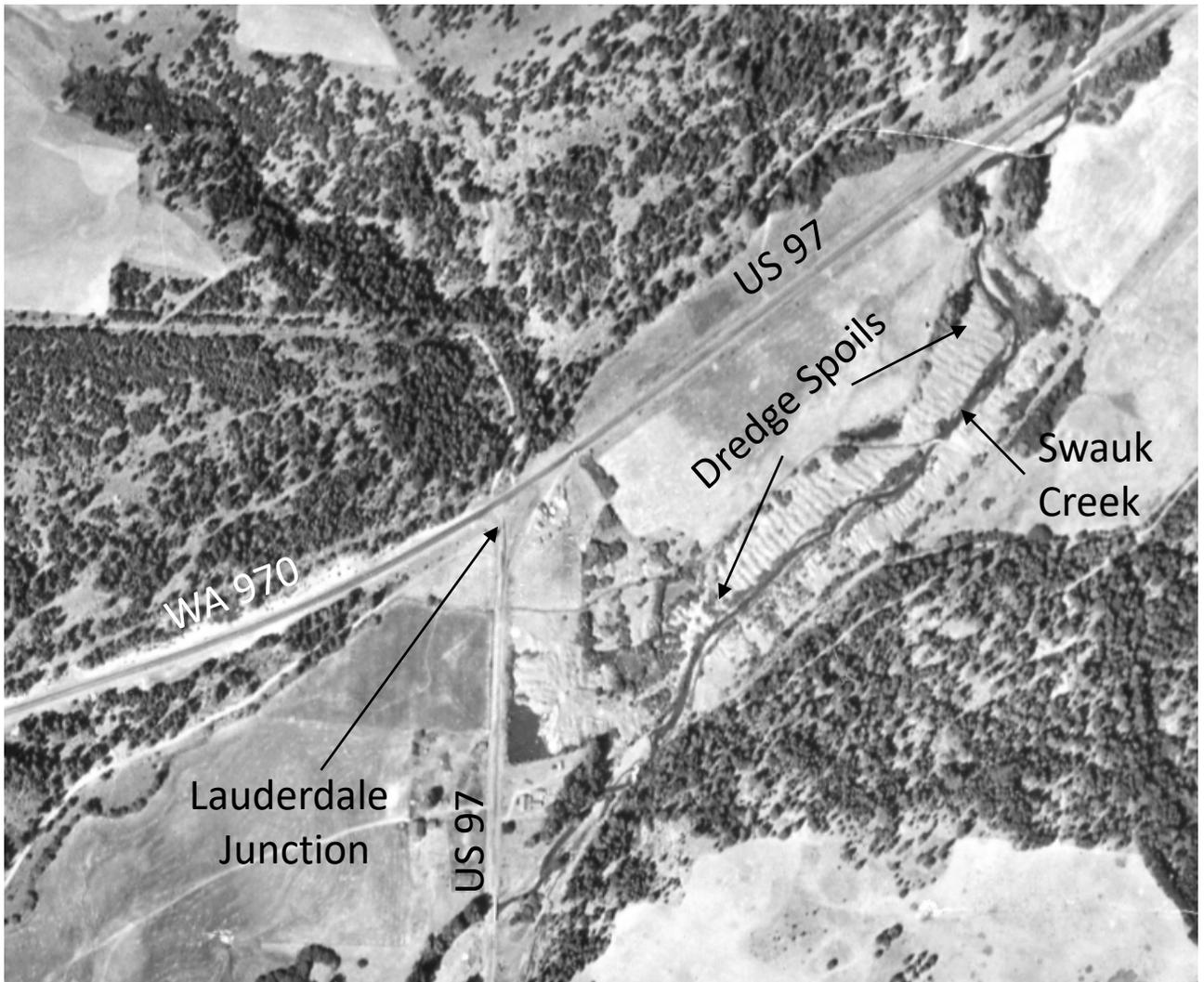


Figure 7. Aerial view of dredge mining spoils on Swauk Creek floodplain near Lauderdale Junction. Kittitas County aerial photograph NJ-2N-69 from 1954 from CWU's Geography Department Central Washington Historical Aerial Photograph Project ([https://www.gis.cwu.edu/geog/historical\\_airphotos/](https://www.gis.cwu.edu/geog/historical_airphotos/)).

# Horse Canyon Overlook to Swauk Creek – Hurley Creek Junction



**Figure 8. Gold dredge on unknown portion of Swauk Creek ca 1915. Source: Frederick Krueger Collection, Archives and Special Collections, Brooks Library, Central Washington University, Ellensburg, WA).**

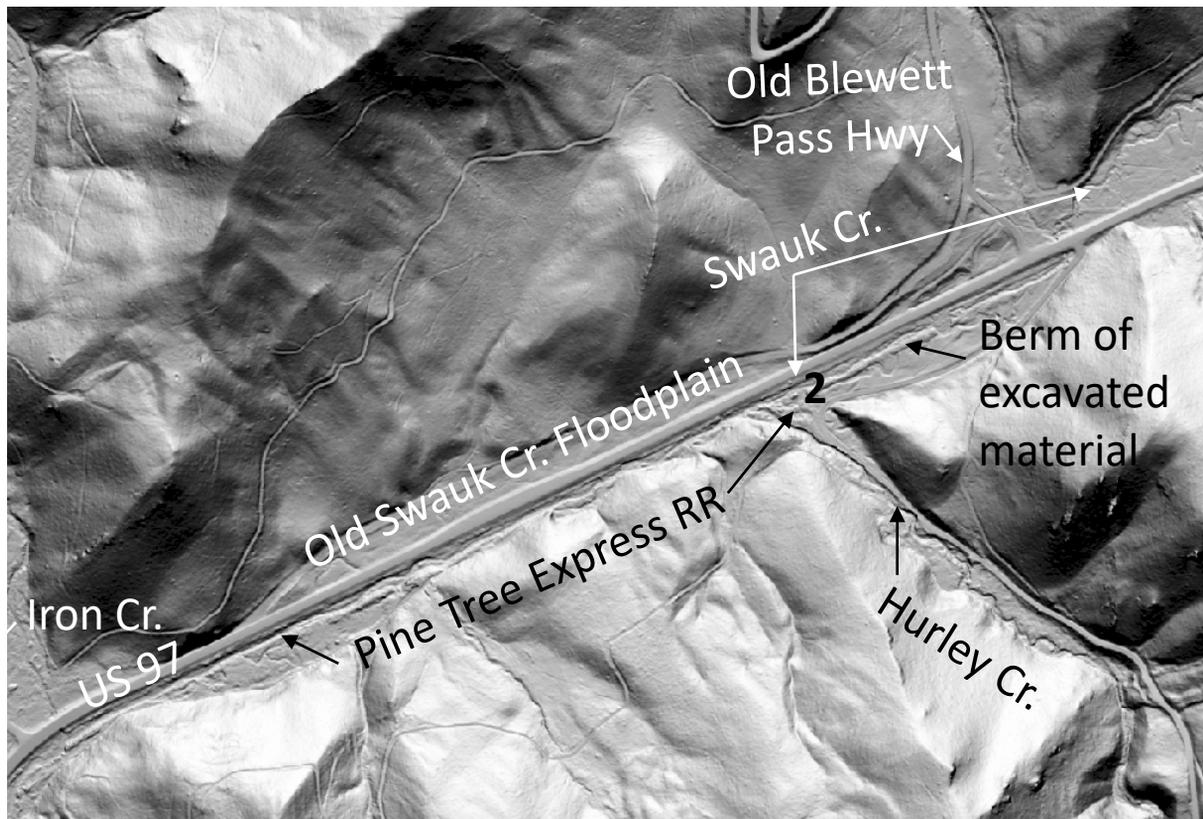
## Stop 2—Swauk Creek-Hurley Creek Junction

**Getting our bearings.** We are located at the junction of Swauk Creek and Hurley Creek (**Figures 9 & 10**). The GPS coordinates for the site are 47.323398° N & 120.677147° W.

**Logging.** The ponderosa pine and Douglas fir forests of the Swauk Watershed have been logged one or more times over time. It is unclear if the first logging in the Swauk Watershed (like that in the Teanaway River watershed) involved the use of “splash dams” which were blown up to create floods that transported logs to the Yakima River. I suspect that Swauk Creek did not have sufficiently large flow for splash dams to work. We do know that the Cascade Lumber Company logging railroad line was laid up Swauk Creek beginning in 1930 (Henderson, 1990). Railroad logging continued here until 1944. Our route up Swauk Creek paralleled and sometimes even overlaid the Cascade Logging Company’s “Pine Tree Express” railroad route of the early to mid 20<sup>th</sup> century (**Figure 11**). Rail lines were laid up many of the tributary valleys in the Swauk where they were used to haul out logs (CWU undergraduate =>Erickson, 2001). Camps were established in some of these tributary valleys with the main camp in the First Creek drainage near Lauderdale Junction (**Figure 12**). One such branch line terminated in a camp in upper Hurley Creek (**Figure 11**).

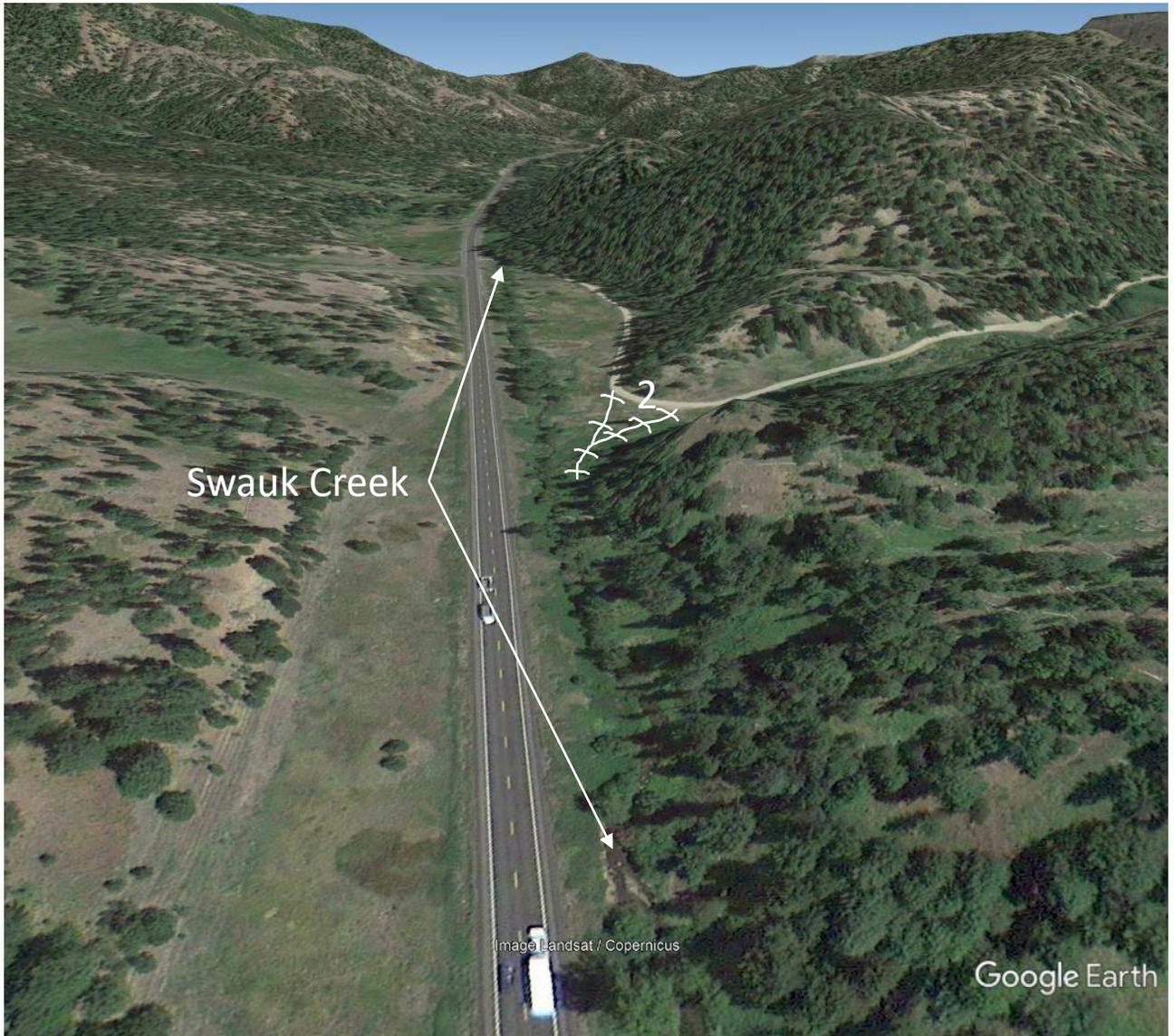
## Stop 2—Swauk Creek-Hurley Creek Junction

**Railbeds, roads & streams.** Railbeds, like subsequent roads, confined Swauk Creek and its tributaries to their channels therefore preventing them from spilling out on their floodplains during high flows. Confinement also meant that the natural tendency to meander was prevented. This meant that these streams used their energy to erode vertically resulting in incised channels. Swauk Creek and Hurley Creek are incised and therefore disconnected from their floodplains. Here, the Pine Tree Express likely played a minor role in this confinement as it hugged the south side of the floodplain (Figures 9 & 10). The original US 97 was built just above the floodplain on the north side of Swauk Creek Valley. This was a good design in terms of impacts on streams. However, when the current version of US 97 was constructed in the 1950's, it went up the middle of the floodplain therefore confining Swauk Creek to the south side of the floodplain (Figures 9 & 10). Further, it appears that a straight channel was excavated for Swauk Creek on the south side of US 97 and a berm was created from the excavated material immediately south of the creek. The result is that Swauk Creek flows in a canal-like channel for nearly a mile here.



**Figure 9. Swauk Creek floodplain in the vicinity of the Swauk Creek - Hurley Creek junction. Bold number indicates location of Stop 2. Source: Washington Lidar Portal (<https://lidarportal.dnr.wa.gov/>).**

## Stop 2--Swauk Creek – Hurley Creek Junction



**Figure 10. Oblique view up Swauk Creek Valley and US97 near the junction of Swauk Creek and Hurley Creek. Note the canal-like nature of Swauk Creek to the south of US 97, and the abandoned floodplain to the north of the highway. Also, note the Pine Tree Express alignment near the junction. Bold number indicates approximate field trip stop location. Source: Google Earth Pro.**

# Stop 2--Swauk Creek – Hurley Creek Junction

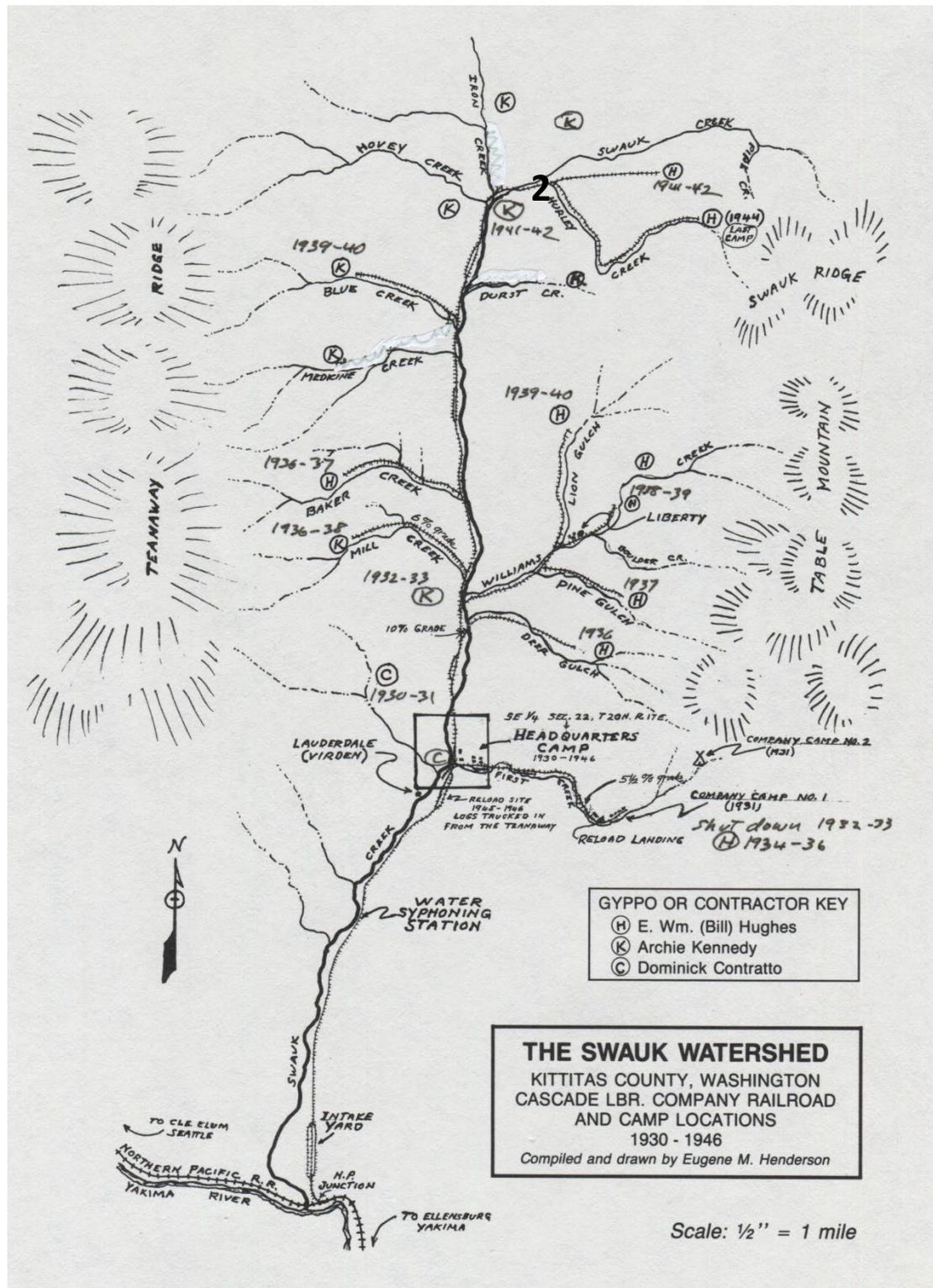


Figure 11. Railroad logging lines in the Swauk Watershed. Bold number indicates approximate location of Stop 2. Source: Henderson (1990).

## Stop 2—Swauk Creek –Hurley Creek Junction



Figure 12. Camp 1 in the snow on First Creek in 1931. Source: E.M. Henderson, "Logging" (1931), *Frederick Krueger Photographs*. 109.

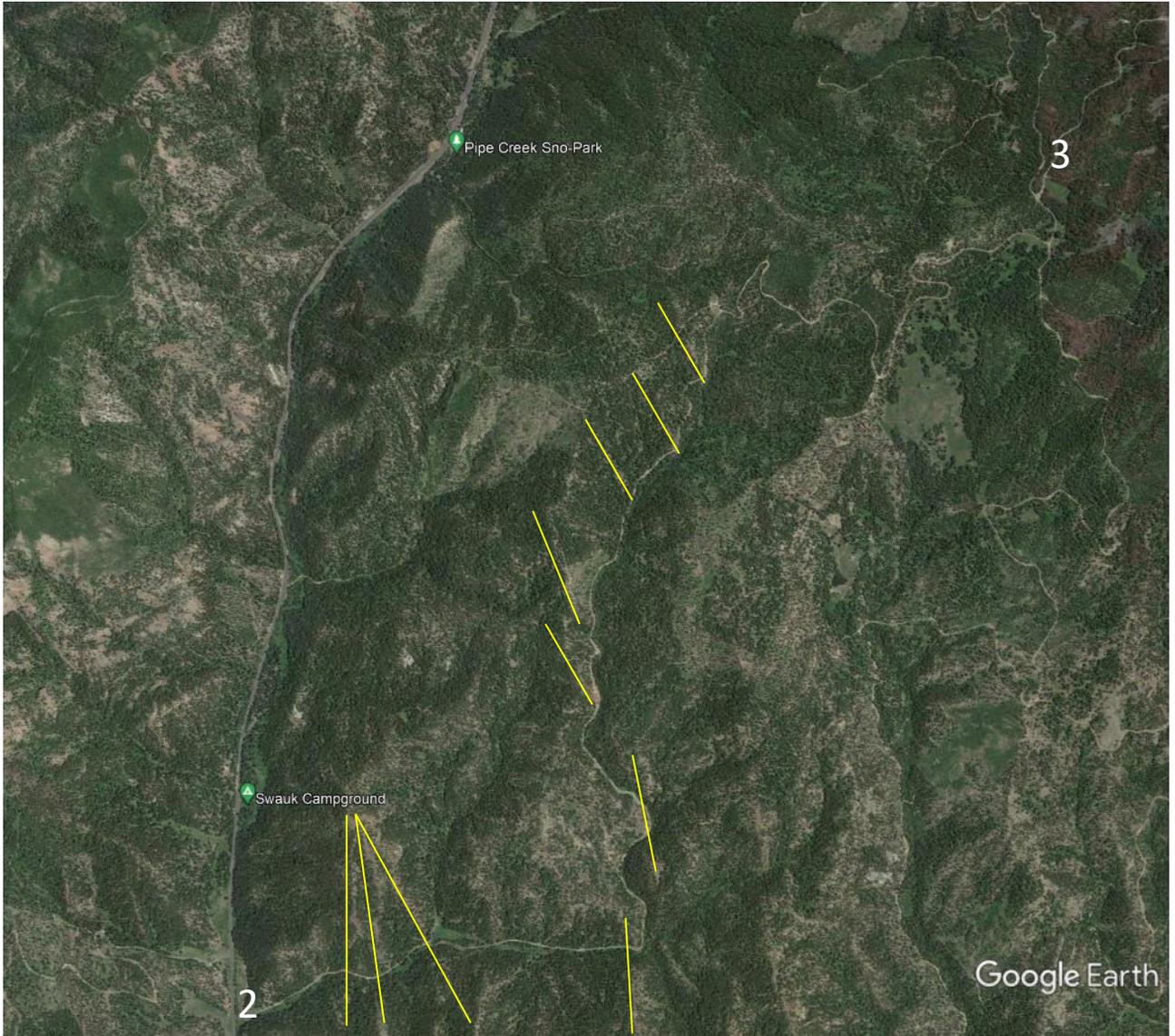
[https://digitalcommons.cwu.edu/frederick\\_krueger/109](https://digitalcommons.cwu.edu/frederick_krueger/109).

## Swauk-Hurley Creek Junction to Upper Swauk Creek

**From here.** Continue up NF-9711 for ~6.1 miles to the junction with NF-9712. Turn left onto NF 9712 and continue for ~0.2 miles to the junction with NF 9716. Bend right at this junction and remain on NF 9712 for another ~0.1 mile. Park alongside the road here taking care to leave room for vehicles to pass.

**Railroads, sandstone & dikes.** The route to Stop 3 partially follows the old Hurley Creek Pine Tree Express branch line for approximately 4-5 miles upvalley. Light gray bedrock outcrops are sandstones of the Swauk Formation. Conversely, brownish red outcrops are dikes of the Teanaway Basalts. The road crosses through at least 10 dikes along this route (Figure 13). As ridges, these dikes often add outward curves to the road. Notice how the dikes and sandstone exposure diminish as you near Stop 3.

# Swauk-Hurley Creek Junction to Upper Swauk Creek



**Figure 13. Vertical airphoto view of Hurley Creek road with Teanaway basalt dikes superimposed on the road. Bold numbers indicate approximate locations of field trip stops 2 and 3. View to the NE. Source: Google Earth Pro.**

## Stop 3: Upper Swauk Creek

**Getting our bearings.** We are parked just above the junction of USFS roads NF-9716 and NF-9712 on NF-9712 (Figure 14). The GPS coordinates are 47.304759°N & 120.599012°W. From here, we will walk up the unmarked road on the south side of NF-9712 for about 0.3 mile to the road's end. This road takes off from NF-9712 just uphill from the yellow sign announcing that you are entering a burned area. We have climbed nearly 2,000 feet to get here from Stop 2—we are now at about 4,960 feet elevation and are on the margins of Eastside forest and subalpine forest.

**Swauk Watershed mass wasting:** Back in the late 1990's and early 2000's, I mapped mass wasting throughout the Swauk Watershed using airphotos, topographic maps, and field work. A key finding was that 38% of the watershed had experienced visible mass wasting in the past. Most of this mass wasting occurred in the high headwaters of the watershed (Figure 15), especially on the flanks of Red Top and Table mountains. Over time, this should have led to an expansion of the watershed boundaries (especially on the east side) as mass wasting led to *headward recession*. The escarpments and “scallops” we see above are indications of this recession. Therefore, mass wasting has determined the northern and western extent of the Columbia River Basalts here. These basalts should have initially been more extensive in what is now the Swauk Watershed extending north and west. Other key evidence of mass wasting include “benchy” and “hummocky” terrain (Figure 16). The hummocks are often filled with ponds and wetlands (Figure 16) therefore creating landscape diversity.

**Types of mass wasting.** I identified 156 discrete mass wasting features that include rock fall, slide, flow, and slide flows (Figures 15 & 17). Rockfall is often seen as large talus slopes (Figure 14). These are common on the faces of high elevation escarpments in the basin. Rockfall is enhanced by *joints* (i.e., fractures) in the rock. Such jointing is very common in the Columbia River Basalts of this portion of the watershed. Rockfall operates on the escarpments created by slides. Slides are associated with weak layers below. You can see one such bed (the sedimentary Roslyn Formation) in Figure 14. Slides result in hummocky terrain downslope of escarpments. Flows form occur under wetter conditions that mobilize finer textured sediments. Flows result in channel-like features with berms at the margins. A wetter climate and earthquake activity may have triggered mass wasting activity over time. Much of this area is a combination of slides and flows (i.e., slide flows) because they retained characteristics of both—i.e., they initiate as slides in their upper portions and transition into flows in their toes.

## Stop 3: Upper Swauk Creek



**Figure 14. Northwest face of Table Mountain. Note the Table Mountain escarpment and the “benchy” terrain below. The reddish tinge of the forest was caused by the Table Mountain Fire in September-October 2012. Bold number indicates approximate location of field trip stop 3. X indicates where we will walk to. Oblique view toward the southeast. Source: Google Earth Pro, 07/09/2013.**

# Stop 3: Upper Swauk Creek

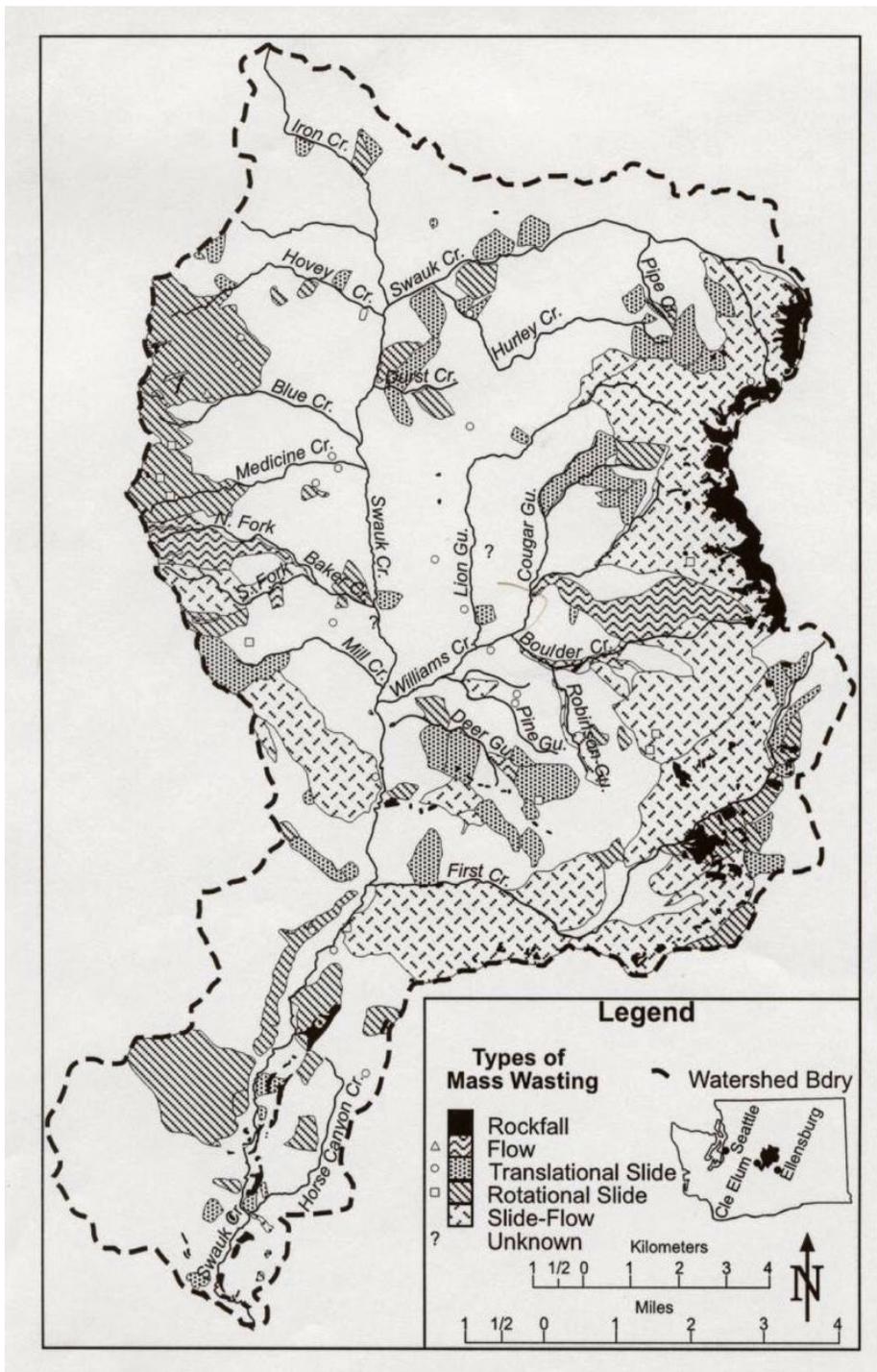
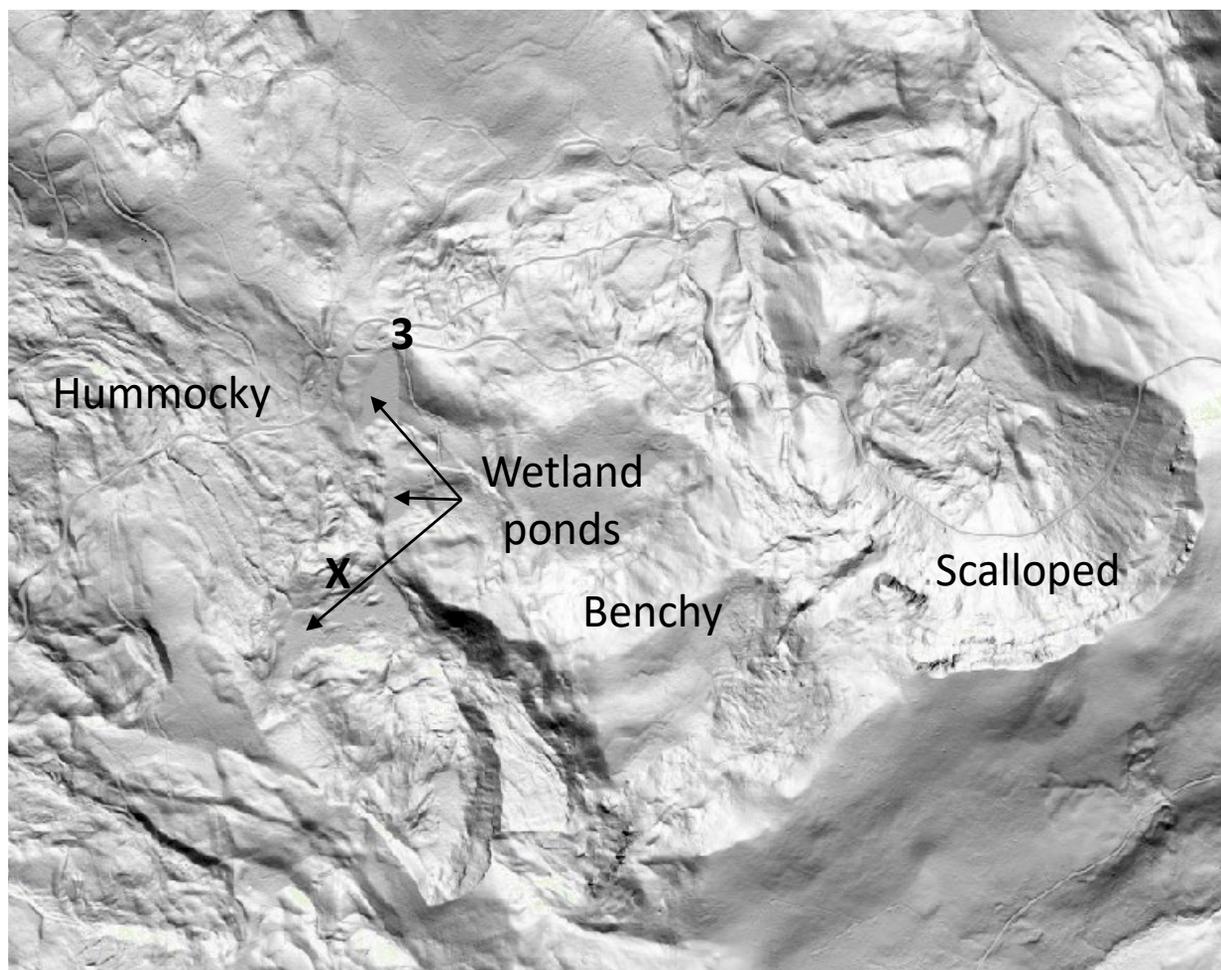


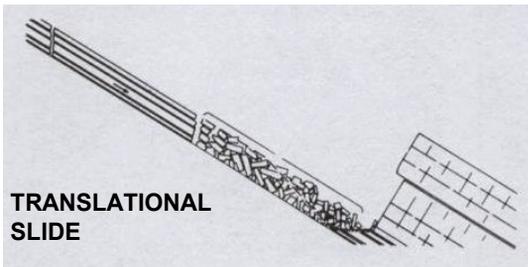
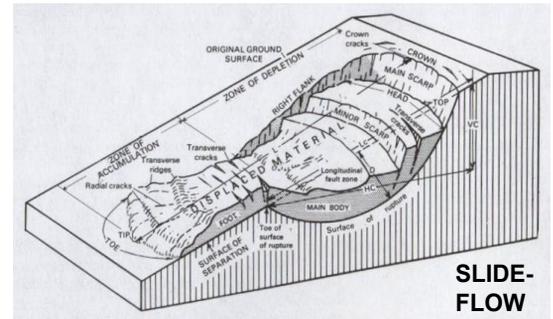
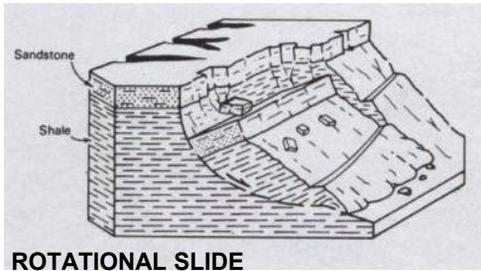
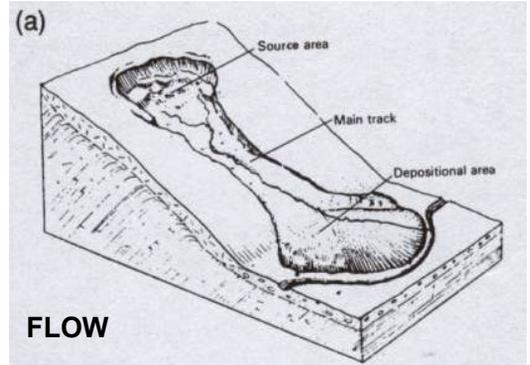
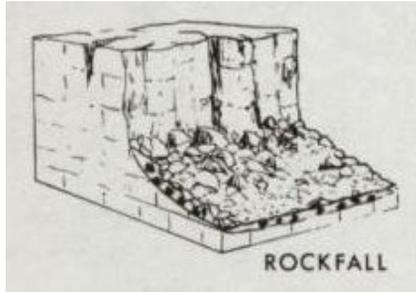
Figure 15. Extent and types of mass wasting in Swauk Watershed. Source: Lillquist (2001).

## Stop 3—Upper Swauk Creek



**Figure 16. Lidar view of mass wasting in the vicinity of Stop 3. Note the scalloped, benchy, and hummocky terrain. Wetland ponds often occupy the depressions in the hummocky terrain, especially in spring and early summer. Each indicate mass wasting. Bold number is approximate parking location for Stop 3. X indicates where we will walk to from the parking spot. North is at the top of the image. Source: Washington Lidar Portal (<https://lidarportal.dnr.wa.gov/>).**

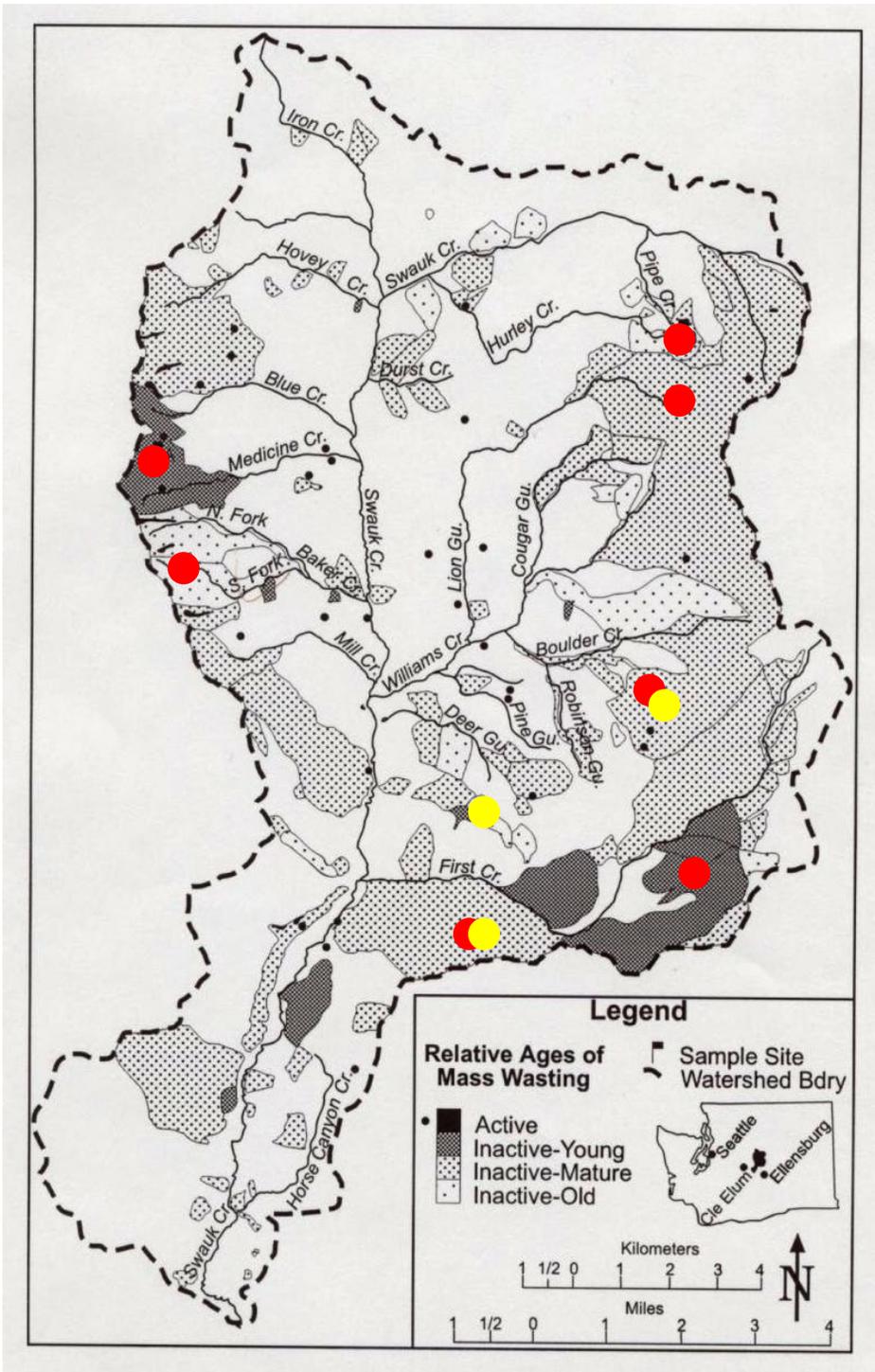
# Stop 3: Upper Swauk Creek



**Figure 17. Different types of mass wasting identifiable on vertical airphotos. Source: various.**

**Ages of Swauk Watershed mass wasting.** Based on surface morphology, vegetation cover, and toe relationships with floodplains, streams, and terraces, I mapped the relative ages of all mass wasting features in the watershed. This work suggests that most mass wasting is inactive and mature (i.e., it occurred a significant amount of time before present but not so long that the features have lost their morphological character. This begs the question of how old these features actually are. Using limited radiocarbon and tephra (i.e., volcanic ash) dating, CWU undergraduate student Henry Sanderson and I (Lillquist, 2001; Sanderson, 2002) collected datable material from the relative dated features to determine their absolute ages (Figure 18; Table 1). The absolute ages suggest that inactive-young features are less than ~6,000 <sup>14</sup>C years old, inactive-mature are ~6,000-~10,000 <sup>14</sup>C years old, and inactive-old are >~10,000 <sup>14</sup>C years old. Much more work needs to be done here to clarify this.

# Stop 3: Upper Swauk Creek



- Radiocarbon dates = ●
- Tephra date = ●

Figure 18. Relative ages of all mass wasting and absolute ages on a select few mass wasting features in the Swauk Watershed. Based on our fieldwork: Inactive young = <6,000 14C yrs; Inactive-mature = 6,000-10,500 14C yrs, and Inactive-old = >10,500 14C yrs. Sources: Lillquist (2001) and Sanderson (2002).

## Stop 3—Upper Swauk Creek

**Table 1. Dated mass wasting features in Swauk Watershed. Source: Lillquist (2001); Sanderson (2002).**

Sample #	Feature (#)	Location	Coordinates (UTM)	Lab #	Material	<sup>14</sup> C Age	Relative Age	Source
WaReCa24100001	Rotational Slide (170)	First Cr.	530825N 681675E	153220	Seed	4550 +/-50	<i>Inactive</i> <i>-Young</i>	Sanderson (2002)
WaReTo11099801	Rotational Slide (354)	U. Medicine Cr.	5239916m N 669900mE	125973	Charcoal	5930 +/-100	<i>Inactive</i> <i>-Young</i>	Lillquist (2001)
WaReTo07280101	Slide-Flow (476)	Hurley Cr.	5237320m N 670110mE	161397	Charcoal	1790 +/- 40	<i>Inactive</i> <i>-Mature</i>	Sanderson (2002)
WaReCa01110002	Slide-Flow (476)	U. Swauk Cr.	5234900N 680975E	153221	Wood	4190 +/-40	<i>Inactive</i> <i>-Mature</i>	Sanderson (2002)
WaBlPa27099801	Translation . Slide (478)	U. Pipe Cr.	5242413m N 680839mE	125974	Organic Seds	6880 +/-70	<i>Inactive</i> <i>-Mature</i>	Lillquist (2001)
WaSwPr06070101	Rotational Slide (151)	U. First Cr.	5231925N 677250E	Same as sample	Tephra	6,850	<i>Inactive</i> <i>-Old</i>	Sanderson (2002)
WaBlPa09230101	Slide-Flow (2)	U. Baker Cr.	5239800N 669800E	161396	Charcoal	9,590 +/- 60	<i>Inactive</i> <i>-Old</i>	Sanderson (2002)
WaSwPr14110003	Slide-Flow (156)	U. First Cr.	5229500N 676925E	153222	Peat	10,540 +/- 70	<i>Inactive</i> <i>-Old</i>	Sanderson (2002)

## Upper Swauk Creek to Lion Gulch

**From here.** Turn around and follow NF 9712 ~3 miles to junction of NF-9712 and NF-9718. Continue right on NF-9712. At another junction in about ~1 mile, stay on NF-9712 by veering left. In another ~1.25 miles, you will reach the junction of NF-9712 and NF-9705. Turn right onto NF-9705. Follow this road uphill for about 0.25 mile. Park in one of the pullouts on either side of the road or along the road. If parking along the road make sure to leave room for vehicles to safely pass.

**Geology.** As you descend into Lion Gulch, notice how you leave the hummocky terrain behind. Light gray sandstone and rusty red basalt replace the hummocks. You have essentially gone from a landscape that is entirely mass wasting debris to one that only has scattered mass wasting features.

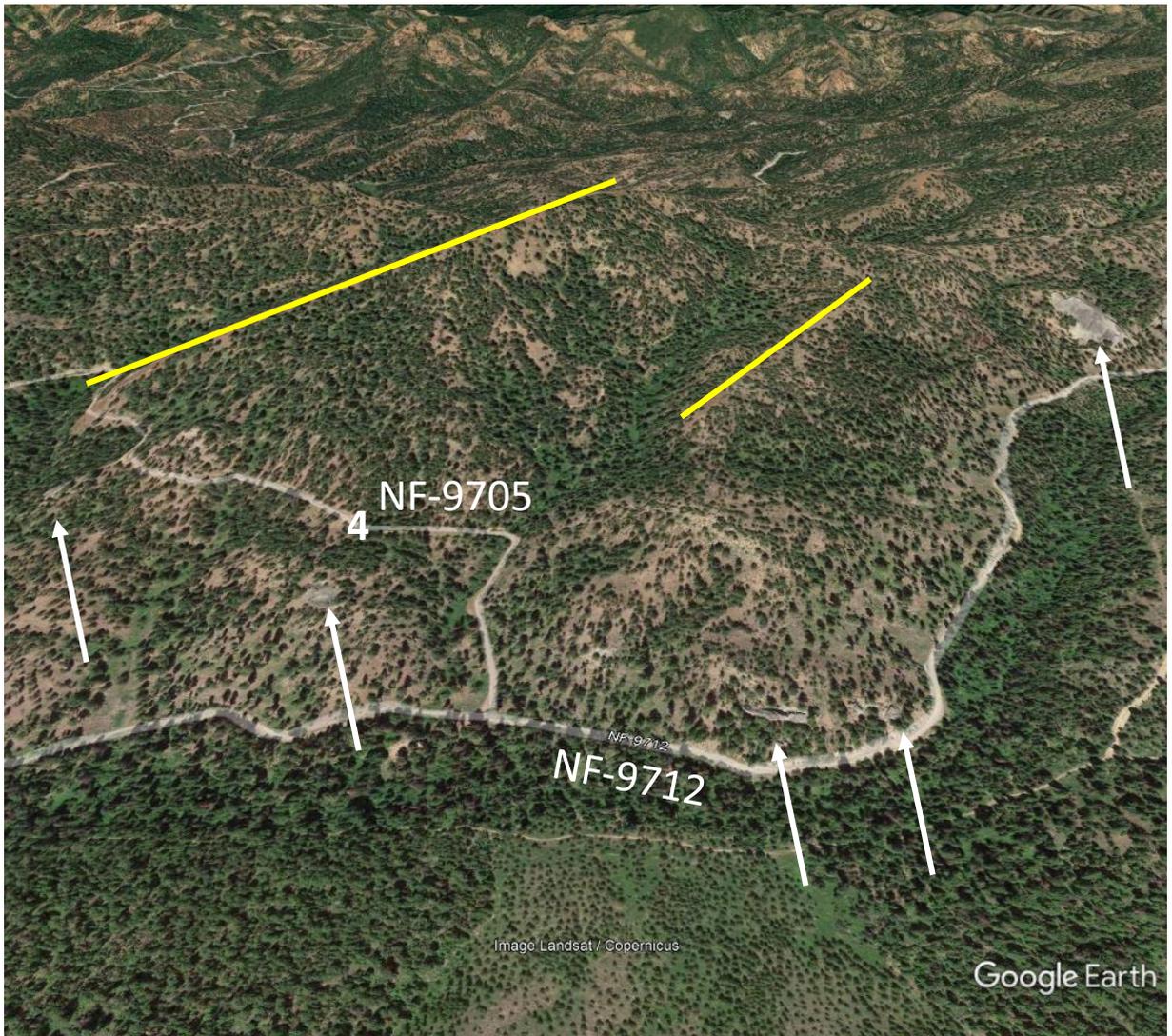
## Stop 4: Lion Gulch

**Getting our bearings.** We are located near a large sandstone “tor” along NF 9705 (Figure 19). The gps coordinates are: 47.293094°N & 120.661023°W.

**Swauk Formation.** The Swauk Formation covers much of the Swauk Watershed (Figure 2). The Swauk Formation is a sedimentary unit that consists mostly of fine to medium-grained, light-colored sandstone. Siltstone, shale, and conglomerate beds interbed the sandstone layers (Tabor and others, 1982). The Swauk Formation may be as thick as 26,000 ft! However, this is an estimate because of measurement difficulties caused by folding and faulting, intrusion of Teanaway Basalt dikes, and a lack of distinct marker beds. Thicknesses in the eastern portion of the Swauk Formation (including the Swauk Watershed) are better known. Here, there are approximately 13,000 ft of sedimentary rock (Taylor and others, 1988). The lower portion is mostly arkosic sandstone (i.e., feldspar-rich sandstone derived from silicic igneous rocks) that they interpret was deposited in low energy streams flowing to the south southwest. The upper ~6500 ft consists of conglomerates, shales, and sandstones that indicate flow to the northeast (Taylor and others, 1988). A U-Pb zircon date on sandstone near the base of the Swauk Formation yielded a date of about 59.9 million years and *tuff* (i.e., hardened volcanic ash) within the upper Swauk Formation dated at about 51.5 million years (Eddy and others, 2016).

The Swauk Formation was folded, creating a west-northwest trending fold belt, between about 51 and 49 million years ago (Eddy and others, 2016). Similarities in sediment, paleocurrent indicators, and ages suggests that the Chuckanut Formation of northwestern Washington and the Swauk Formation were deposited in the same basin—the Swauk basin—then offset by the Straight Creek Fault (Eddy and others, 2016) (Figure 20). The west northwest trending fold belt seen here was likely associated with the attempted subduction of the oceanic crust associated with Siletzia (Figure 21).

## Stop 4—Lion Gulch



**Figure 19. Oblique aerial view of sandstone tors (indicated with white arrows) and basalt dikes (indicated with yellow lines) in Lion Gulch in the vicinity of Stop 4. Bold number indicates approximate location of Stop 4. Source: Google Earth Pro.**

# Stop 4—Lion Gulch

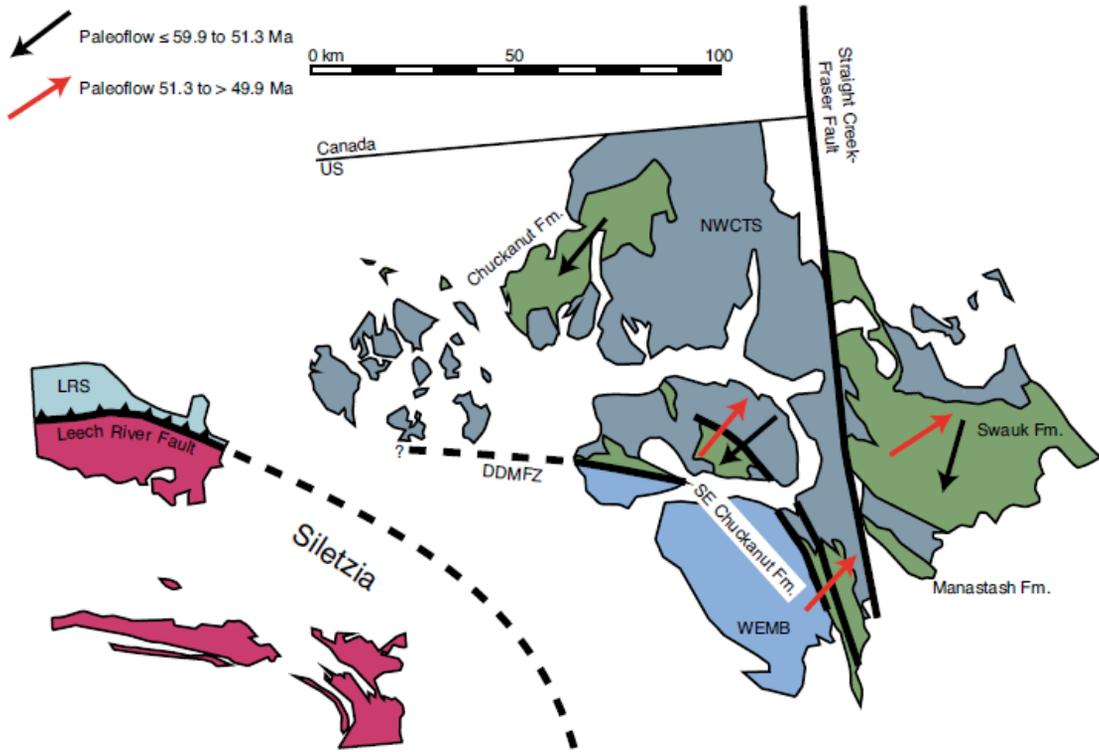


Figure 20. Swauk and Chuckanut formations offset by Straight Creek Fault. Note the paleoflow directions for different time periods. Source: Eddy and others (2016).

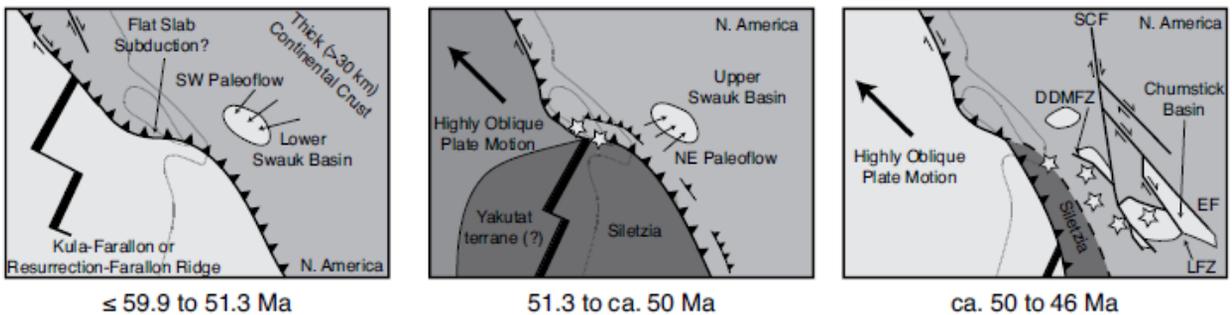


Figure 21. Diagrammatic representation of Swauk Basin pre-accretion of Siletzia (<59.9 to 51.3 Ma), during accretion of Siletzia (51.3-50 Ma), and post-accretion (50 to 46 Ma). Note that igneous activity (including volcanism) (all indicated with stars) was associated with the strike-slip faulting of the post-accretion period. Eddy and others (2016).

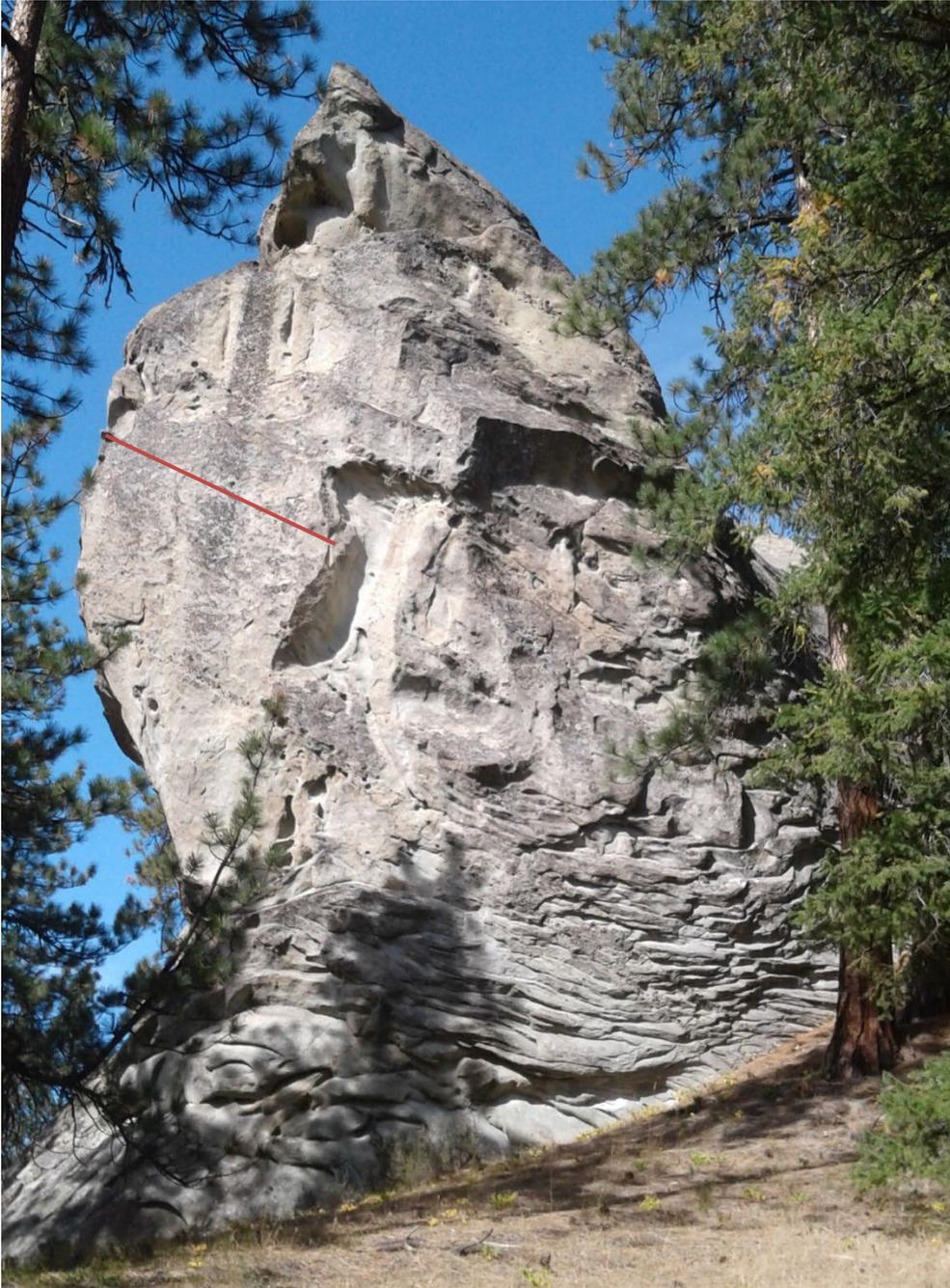
## Stop 4—Lion Gulch

**Landforms of the Swauk Formation.** As you may have seen on the drive to this stop, the Swauk is exposed in numerous roadcuts in the Swauk Watershed. Swauk Formation landscapes generally consist of gently rolling terrain. However, this terrain is often punctuated by asymmetrical, sandstone “*monoliths*” (i.e., “*tors*”) (Figure 22). They are especially common where folding and subsequent erosion has resulted in anti-dip and dip slopes in homoclinal valleys and ridges (Figure 23). Tors have tall, steep downslope sides on the anti-dip slopes and gentle upslope sides (Figure 22). In the Swauk Watershed, these conditions are best met east of Swauk Creek and west of the west face of Table Mountain (Becerra, 2016). Such features are relatively common in other sandstone dominated areas of Central Washington (e.g., Roslyn Formation in the Teanaway Watershed, Chumstick Formation in the Lower Wenatchee River Valley).

**A model for tor formation.** CWU undergraduate researcher Rebeca Becerra (2016) mapped tors in the eastern Swauk Watershed (Figure 24), then proposed a multi-step process in the formation of Swauk monoliths. I have modified these steps a bit: 1) deposition of sands and gravels by west to southwest flowing streams; 2) lithification of these sediments; 3) development of east to northeast trending folds that resulted in tilting of the layers; 4) intrusion of the sandstones and conglomerates by Teanaway Basalt dikes; 5) a second period of folding along a northwest trend that resulted in jointing and drainage reorganizations; 6) structure-parallel stream erosion truncated folds creating *homoclinal ridges*; 7) structure-transverse streams developed on anti-dip slopes isolating *flatirons* from homoclinal ridges; 8) further erosion combined with weathering and mass wasting led to tors characterized by cliff faces on anti-dip slopes and gentler dip slopes; 9) further physical weathering and mass wasting resulted in *overhangs* on anti-dip slopes while chemical and physical weathering resulted in *honeycomb* forms on anti-dip and dip slopes; 10) ongoing weathering and rockfall resulted in backwasting of tors over time (Figure 25).

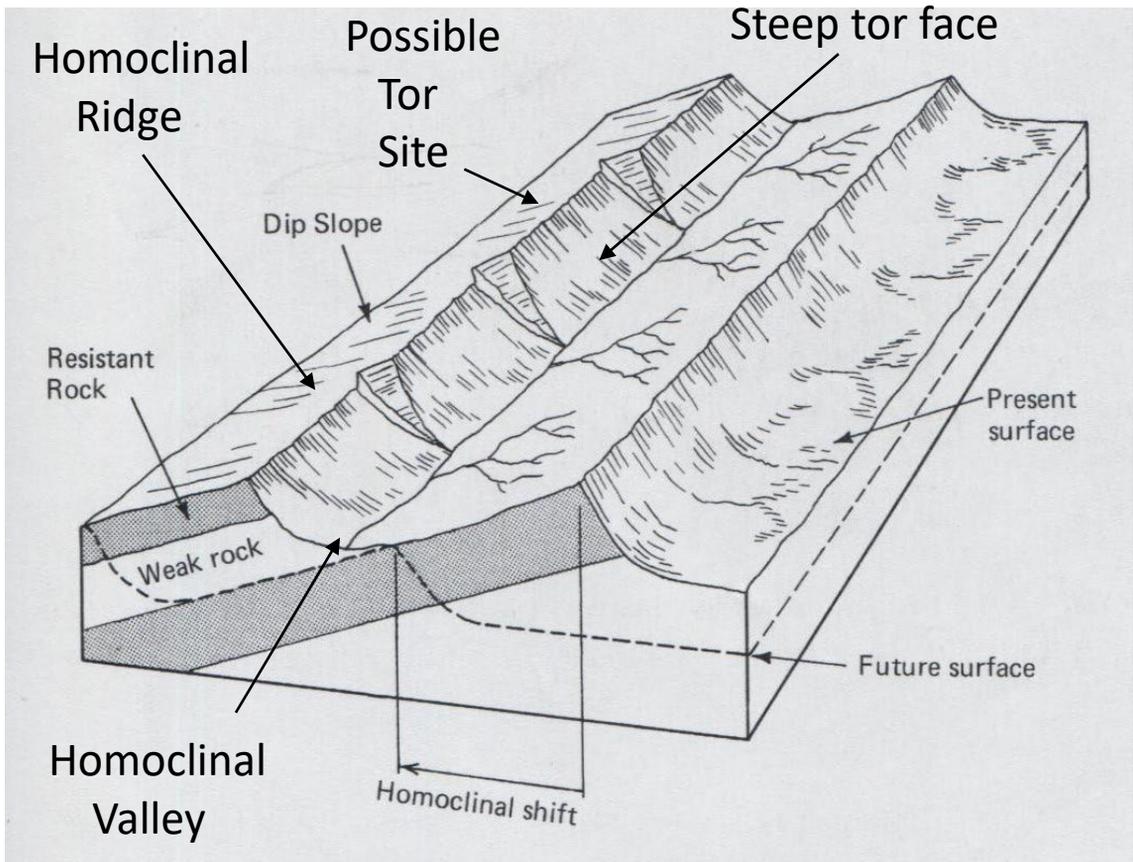
**Ages of tors.** We don’t know when the tors were isolated from the homoclinal ridges. I expect that they were present more than 20,000 years ago because the area was not glaciated. We can comment on how active these features are. The non-lichen covered portions of the monoliths (especially the anti-dip faces) indicate that they are actively forming through a variety of weathering processes as well as rockfall. Conversely, the dip slopes of monoliths often appear more stable based on their lichen cover and less rubble at their bases.

## Stop 4—Lion Gulch



**Figure 22** Side view of sandstone tor at stop 4 in Lion Gulch, Swauk Watershed. Red line highlights the dip of beds from right to left. Note the steep, anti-dip face (left). Also note the honeycomb features. Author photo, September 2022.

# Stop 4—Lion Gulch



**Figure 23. Homoclinal ridges and valleys, and possible locations for sandstone tors to form. Source: Bloom (1991, p. 263).**

# Stop 4—Lion Gulch

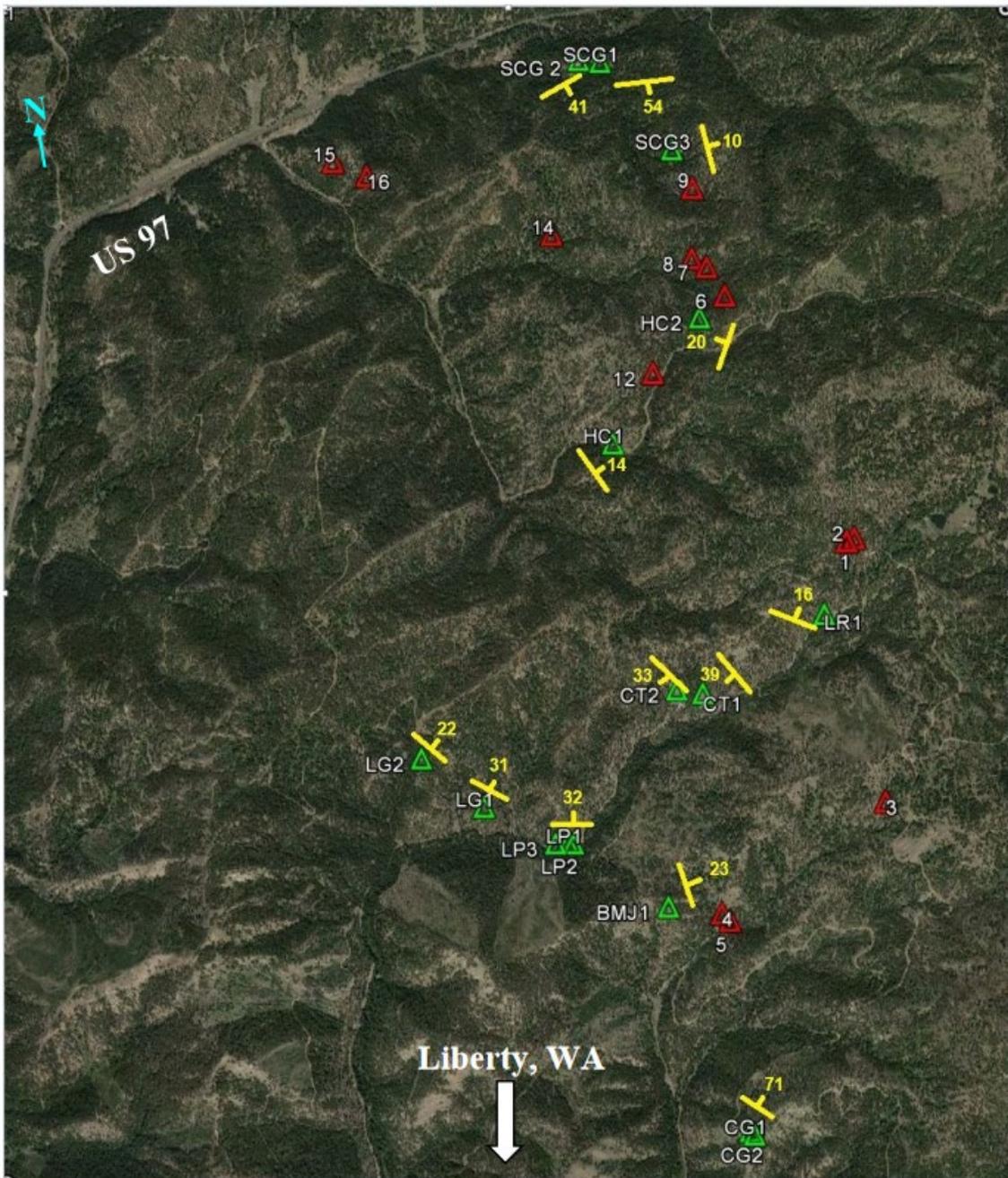


Figure 24. Green and red triangles are sandstone monoliths identified in northcentral Swauk Watershed. Green indicates 16 features identified on Google Earth and visited in the field. Red monoliths are those 16 features only identified on Google Earth. Source: Becerra (2016).

## Stop 4—Lion Gulch



**Figure 25. View up at the honeycomb anti-dip slope face of tor at Stop 4, Lion Gulch. Author photo, September 2022.**

## Lion Gulch to Upper Durst Creek

**From here.** Continue uphill on NF 9705 for approximately 2 miles. At Stop 5, there are pullouts on both sides of the road, and parking on a side road just before (east) the field stop site.

# Stop 5: Upper Durst Creek

**Getting our bearings.** We are located at 47.300904°N, 120.672975°W on USFS road NF 9705. After parking, we will hike along the crest of a Teanaway basalt dike (Figure 26). From this ridge crest we should have a great view of Redtop Mountain to the west and Table Mountain to the east. We can also see the higher peaks of the Wenatchee Range including Navaho and Earl peaks, and Mt. Stuart of the Stuart Range.

**Teanaway Formation.** The Teanaway Formation was first described by Russell (1893, 1899), Smith (1903, 1904), and Smith and Calkins (1906). The formation consists of basalts (as dikes and flows) plus lesser quantities of andesite, rhyolite, rhyolite ash-flow tuffs, and some sedimentary rock (Tabor & others, 1982). Flow thicknesses range from 2,600 to 7,000 feet west of the Swauk Watershed. Some of the Teanaway basalt dikes may have been “feeder dikes” to shield volcanoes, cinder cones, tuff rings, and even composite cone volcanoes (Clayton, 1973). Rhyolite within the Teanaway Formation dates at about 49.3 million years old (Eddy and others, 2016). The volcanic landforms are so old that little remains of their initial morphologies. Our focus at this stop is on the basalt dikes.

**Teanaway Basalt Dikes.** Basalt dikes form as linear fracture fillings when magma rises and stretches Earth’s crust. If the dikes are geologically young features, they may only be visible in road cuts (Figure 27). If they are geologically old, as are the Teanaway basalt dikes, the rock surrounding them is often eroded away leaving behind a ridge of resistant basalt (Figure 28). This process is known as “differential erosion” and occurs because the basalt is harder than the surrounding rock (e.g., sandstone).

The Teanaway basalt dikes are so numerous they have been described as a “swarm” (Foster, 1958). They extend from west of Wenatchee to west of Lake Cle Elum, and south of Mount Stuart to the lower Teanaway River Valley (Foster, 1958). They are especially common in the Teanaway River Watershed immediately west of the Swauk Watershed.

Dikes in the Teanaway dike swarm range in width from inches to over 100 feet with most tens of feet wide. Lengths may range up to several miles (source?). Teanaway dikes, in the Swauk, as elsewhere in the Teanaway dike swarm, are ridge-formers. Most trend ~northeast (Foster, 1958; Doran, 2009). Up close, the Teanaway dike rock is dark gray on fresh surfaces while it is weathered red in undisturbed weathered outcrop. Dikes often appear red at a landform scale (Figure 28). Vegetation is commonly poorly developed on dike ridge crests. At a landscape scale, dikes may control the topography of an area. Such is the case in upper Durst Creek and upper Lion Gulch (Figure 29).

## Stop 5—Upper Durst Creek

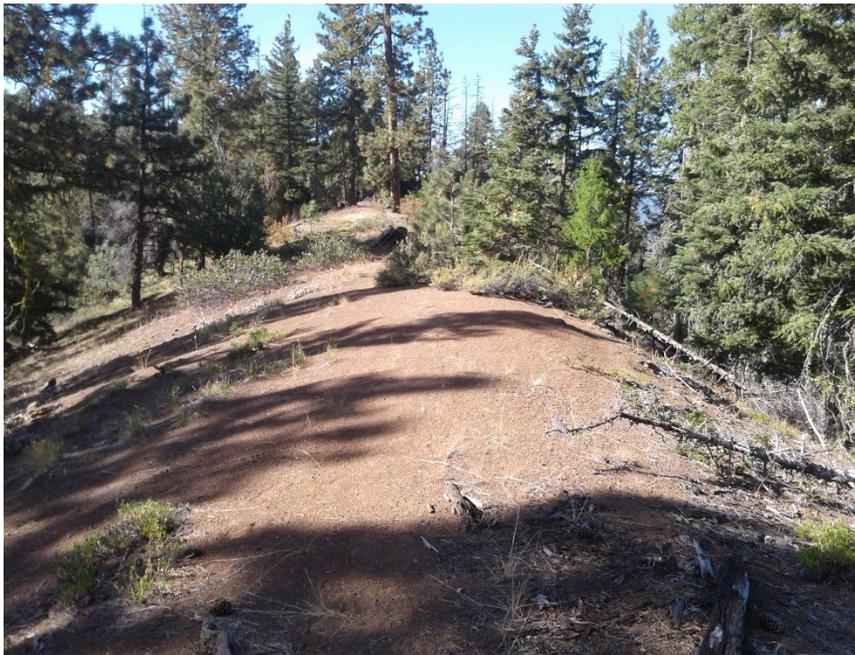


**Figure 26. Teanaway Basalt dike at Stop 2. Bold number indicates approximate parking location. View toward the northwest. Source: Google Earth Pro.**

## Stop 5—Upper Durst Creek

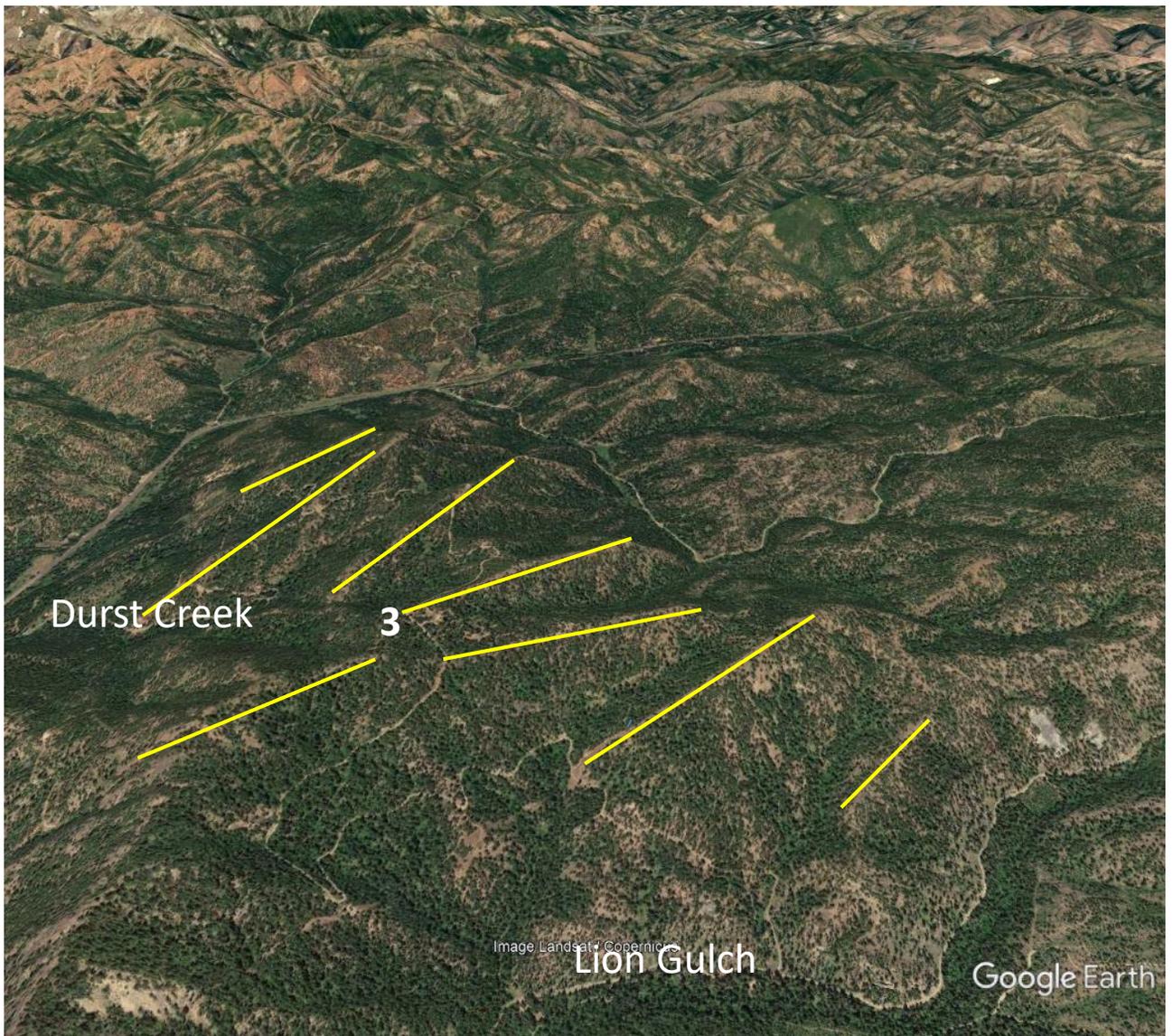


**Figure 27. Horizontal columnar basalt of a dike ridge on Old Blewett Pass Highway. Author photo, September 2015.**



**Figure 28. Ground view along the crest of dike at field trip stop 5. Author photo, September 2022.**

## Stop 5—Upper Durst Creek



**Figure 29. Dikes (yellow lines) in the upper portions of Durst Creek and Lion Gulch areas, northern Swauk Watershed. Note the common orientations of these features. The bold number indicates the approximate location of our field trip stop. Source: Google Earth Pro, 07/01/2017.**

# Stop 5—Upper Durst Creek

## **Teaway basalt dikes (continued)**

The general north-northeast to northeast orientation of dikes (**Figure 29**) indicates northwest-southeast extensional stresses (Doran, 2009; Miller & others, 2022). The generally common orientations of dikes supports a Straight Creek fault movement and possibly movements along the Leavenworth fault (**Figure 20**).

## **Upper Durst Creek to US 97**

**From here.** To return to US 97, continue on NF 9705 ~3.25 miles downhill.

## **Wrap-up**

The Swauk Watershed see today is an amalgam of past factors and processes. These include the complex assemblage of sedimentary and igneous rocks that have been deformed several times over the past 60 million years. Rock assemblages have been shaped by the climate patterns which vary greatly between the low and high elevations of the watershed. Humans have dramatically impacted floodplains over the past century. Future climate change and associated increases in wildfires will likely play a strong role in the watershed's future.

Thanks for supporting the activities of the Ellensburg Chapter of the Ice Age Floods Institute. I hope you have enjoyed your time with us today. If you have questions or comments about this field trip or about physical geography in Central Washington, feel free to contact me at [lillquis@cwu.edu](mailto:lillquis@cwu.edu) or (509) 963-1184. Hope to see you on future field trips!

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