Okanogan Highlands Alliance
Field Trip

Landforms & Landscapes of the Okanogan Highlands

Field Trip Leader:
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Introduction

The Okanogan Highlands contain a diverse array of landforms caused by weathering, streams and rivers, and landslides. However, the Cordilleran Icesheet had the greatest influence on this landscape, and the varied effects of the Cordilleran Icesheet will be the focus of this field trip. Beginning in Tonasket, we will follow the floodplain of the Okanogan River north to Oroville. From Oroville, we will head up the Molson Grade, where we will examine the sediment record of glaciers and glacial lakes, and take a look at how past glaciation has shaped present-day drainage patterns. In Molson, we will stand near the glacier-created divide separating Sidley Lake and west-flowing Ninemile Creek from Molson Lake and east-flowing Baker Creek. In the nearby Mary Ann Creek drainage, we will explore a hummocky landscape of eskers, kames, and terraces left by a stagnating icesheet.   From Mary Ann Creek, we will head southwest to the vicinity of Sitzmark, to discuss icesheet erosion on Knob Hill and cirque glacier erosion on Mt. Bonaparte. Our final stop will focus on the shaping of the Antoine Creek Valley by glaciation, streams, and lakes.

Tentative Schedule

10:00 Depart Tonasket High School
10:30 Stop 1—Molson Grade
11:15 Depart
11:30 Stop 2—Ninemile Road
12:00 Depart
12:15 Stop 3—Molson School
1:15 Depart
1:30 Stop 4—Middle Mary Ann Creek
2:30 Depart
2:45 Stop 5—Knob Hill
3:30 Depart
4:00 Stop 6—Antoine Valley Overlook
4:45 Depart
5:00 Arrive at Tonasket High School

Our Field Trip Stops…

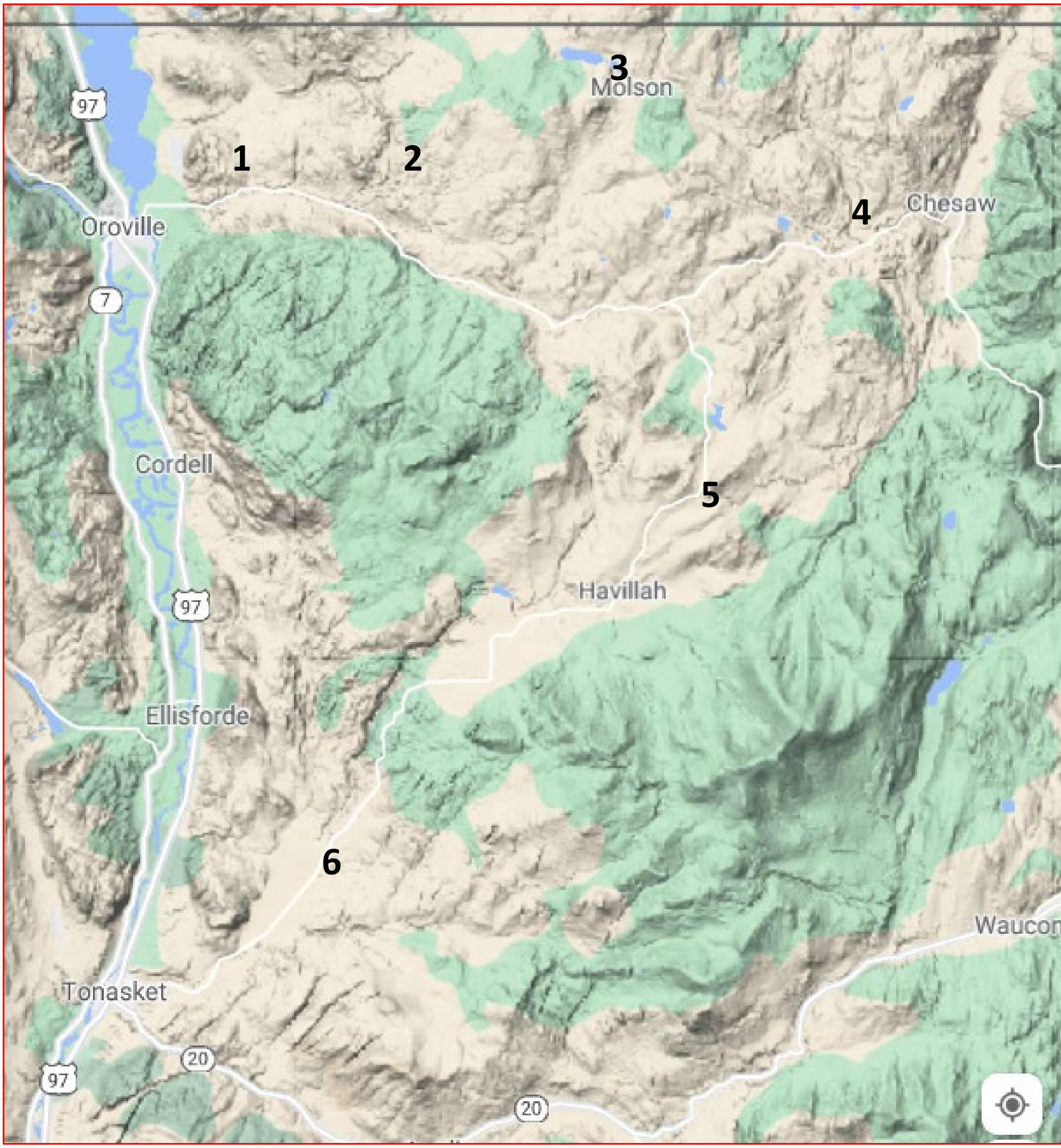

Figure 1. Map view of the approximate locations of field trip stops (noted with numbers). From Google Maps.

Geologic Map

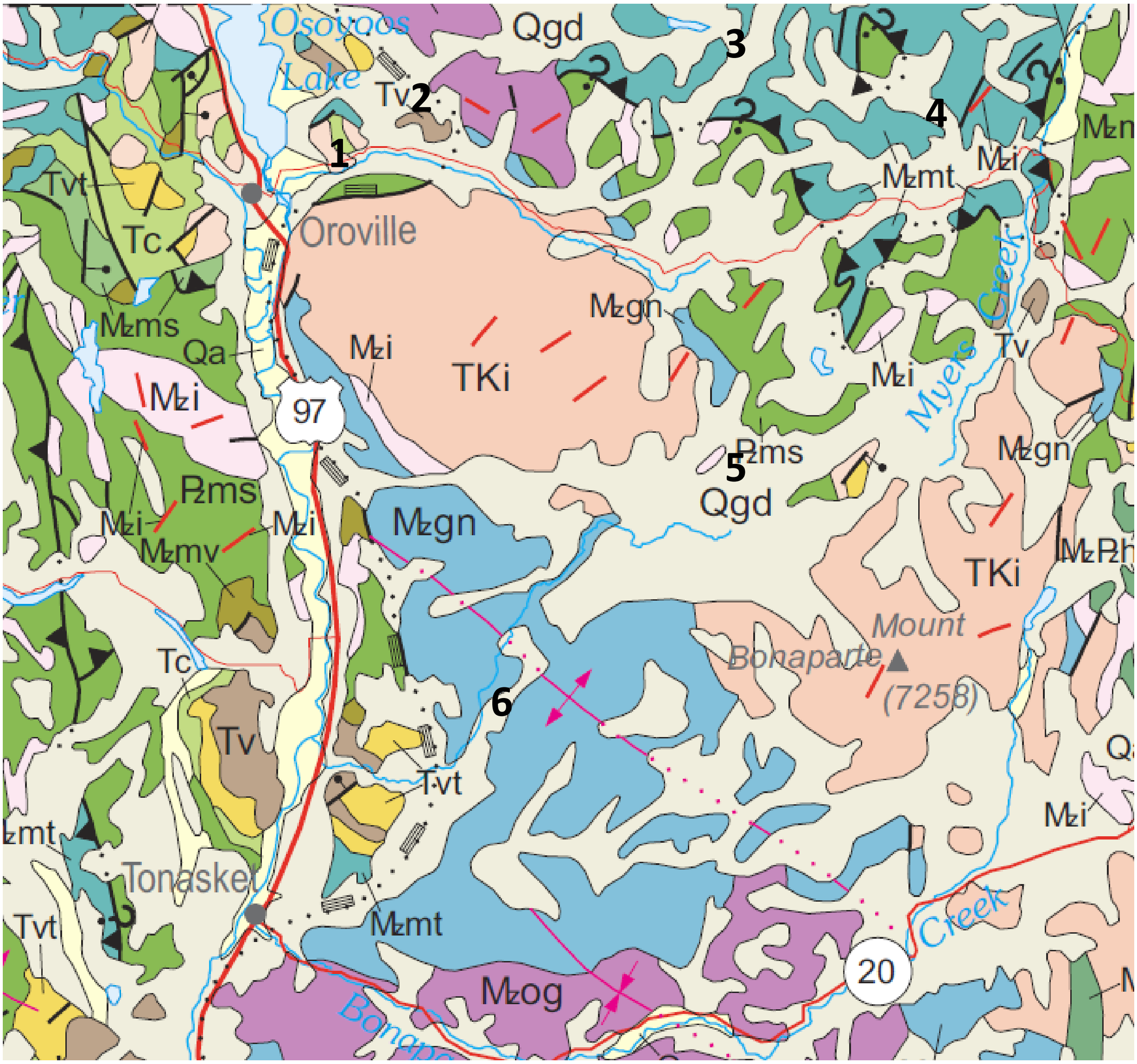

Figure 2. General geologic map of the field trip portion of the Okanogan Highlands. Geologic units key to this trip include (from youngest to oldest):
Qgd=Quaternary glacial drift
Tv = Tertiary volcanics
Tki = Tertiary-Cretaceous intrusive igneous rocks
Mzmt = Mesozoic metasedimentary & metavolcanic rocks
Mzgn – Mesozoic gneiss
Mzog = Mesozoic orthogneiss
Pzms = Paleozoic metasedimentary rocks
Approximate locations of field trip stops noted with bold numbers. From Schuster (2005).

Tonasket to Molson Grade

The route from here…: From Tonasket High School, turn right onto WA 20 and drive west about 0.4 miles to US 97. Turn right onto US 97 and head north about 15.5 miles through Tonasket, Ellisford, and to the far south end of Oroville. Just before US 97 crosses the Okanogan River, turn right onto the Eastside Oroville Road and follow this about 2.0 miles as it winds north to eventually intersect with the Oroville-Chesaw Road. Turn right onto the Oroville-Chesaw Road and follow it about 1.3 miles to a wide pullout on the Molson Grade. The GPS coordinates are: 48.947798° N & 119.386066° W. Park here taking care to pull well to the right and park close to the car in front of yours so we have room for all of the vehicles. This is Stop 1.

Bedrock geology: Our drive north follows the Okanogan Valley, a geologically recent landform eroded in much older rocks. The bedrock from Tonasket to Ellisford is generally Paleozoic marine metasedimentary, Mesozoic metasedimentary and metavolcanic, and Eocene volcanic rocks (**Figure 2**) . *Metasedimentary* and *metavolcanic* just means that they are sedimentary and volcanic rocks that have been metamorphosed (i.e., changed by intense heat and pressure). These old rocks are likely part of a Quesnellia Terrane, a huge block of rock that accreted onto the western edge of North America (Miller and Cowan, 2017). Around Ellisford, we encounter metamorphics and intrusive igneous rocks associated with pre-Tertiary and Tertiary intrusions. Northward, we pass by the Tertiary intrusive igneous rocks of Mt. Hull (Stoffel & others, 1991). The intrusive igneous rocks of Mt. Hull are the most visually distinctive to me (**Figure 3**). These rocks cooled beneath the surface of the earth under tremendous pressure. Subsequent erosion exposed them at the surface. This release of pressure has caused them to fracture in layers parallel to the surface. We call this process *exfoliation*. Pressures on the rocks also resulted in fractures oriented very generally east to west. We call these *joints*. And because the intrusives are hard so they form steep terrain.

A bit of human geography…: Ellisford is located about midway between Tonasket and Ellensburg. Euroamerican settlement here included about 30 families of Dunkards, a religious group that left Germany for Pennsylvania in the 1700's. Descendants of this group moved west to Ellisforde during World War I. Here, they were orchardists (Writers Project, 1941; Kirk and Alexander, 1990).

Tonasket to Molson Grade

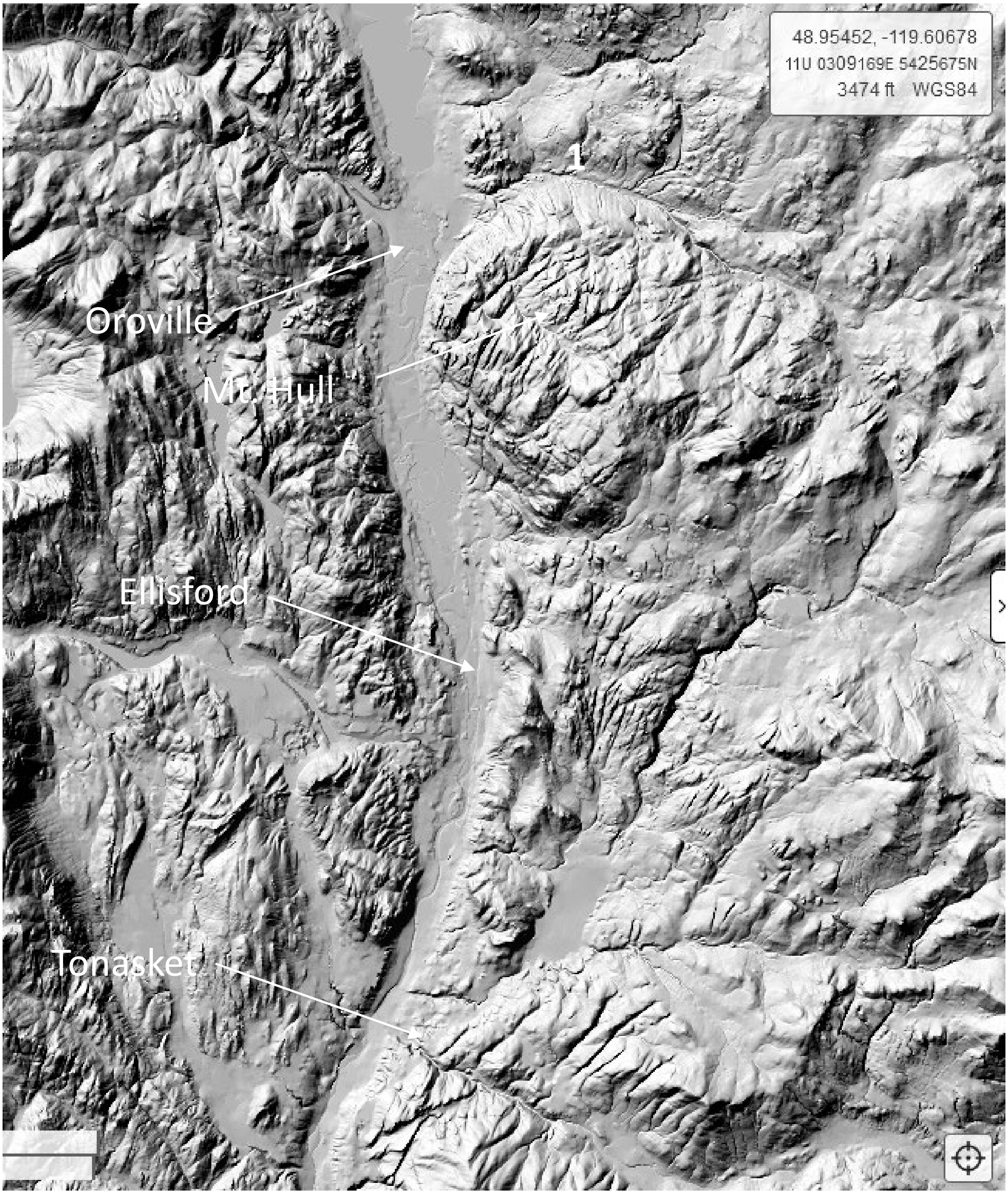

Figure 3. Shaded relief view of the Okanogan Valley between Tonasket and Oroville. Note the widening of the valley north of Ellisford. Also, note the highly jointed nature of Mt. Hull. Bold, white 1 indicates approximate location of Stop 1. From Caltopo.com.

Tonasket to Molson Grade

Okanogan River floodplain: The Okanogan Valley is a product of past tectonic, glacial, and stream activity. The part of the valley from about Ellisford north was partially shaped by a detachment fault. Subsequent glaciation by the Okanogan Lobe of the Cordilleran Icesheet eroded the terrain further. Since recession of the Okanogan Lobe, the Okanogan River has played a key role in the shape of the valley floor. As a result of these processes, the valley and Okanogan River change character between Tonasket and Oroville (**Figures 3 & 4**). The valley is relatively narrow and the river is relatively straight from Tonasket to Ellisford. North of Ellisford, the valley widens and the river takes on a meandering form. In that northern stretch, the valley floor is covered with a sinuous river and numerous lakes that occupy former channels. Horseshoe Lake at the bottom of **Figure 4** is a classic example of this. Large gravel mining operations reflect the importance of stream gravels and sands on the valley floor.

Lake Osoyoos: Lake Osoyoos occupies the glaciated Okanogan Valley floor. This lake likely formed as a *composite kettle* from the deposition of multiple, large chunks of glacial ice. When the ice melted, the large depressions filled with water (Roed, 2011b). The southern end of the lake also appears to be impacted by a large *alluvial fan* that formed at the mouth of Tonasket Creek (**Figure 5**). This fan pushed the Okanogan River to the west and either blocked or partially blocked the outlet channel. Ninemile Creek built a similar alluvial fan that projects out into Lake Osoyoos. Waves and currents in the lake have modified this fan from a rounded to a pointed outline. We call such pointed coastal deposits *cuspate spits*. Lake Osoyoos is somewhat unique in having a number of cuspate spits on its shorelines (**Figure 5**). This may reflect the numerous sediment-loaded streams that have deposited their loads into the lake as well as wave action modifying these deposits.

Tonasket to Molson Grade

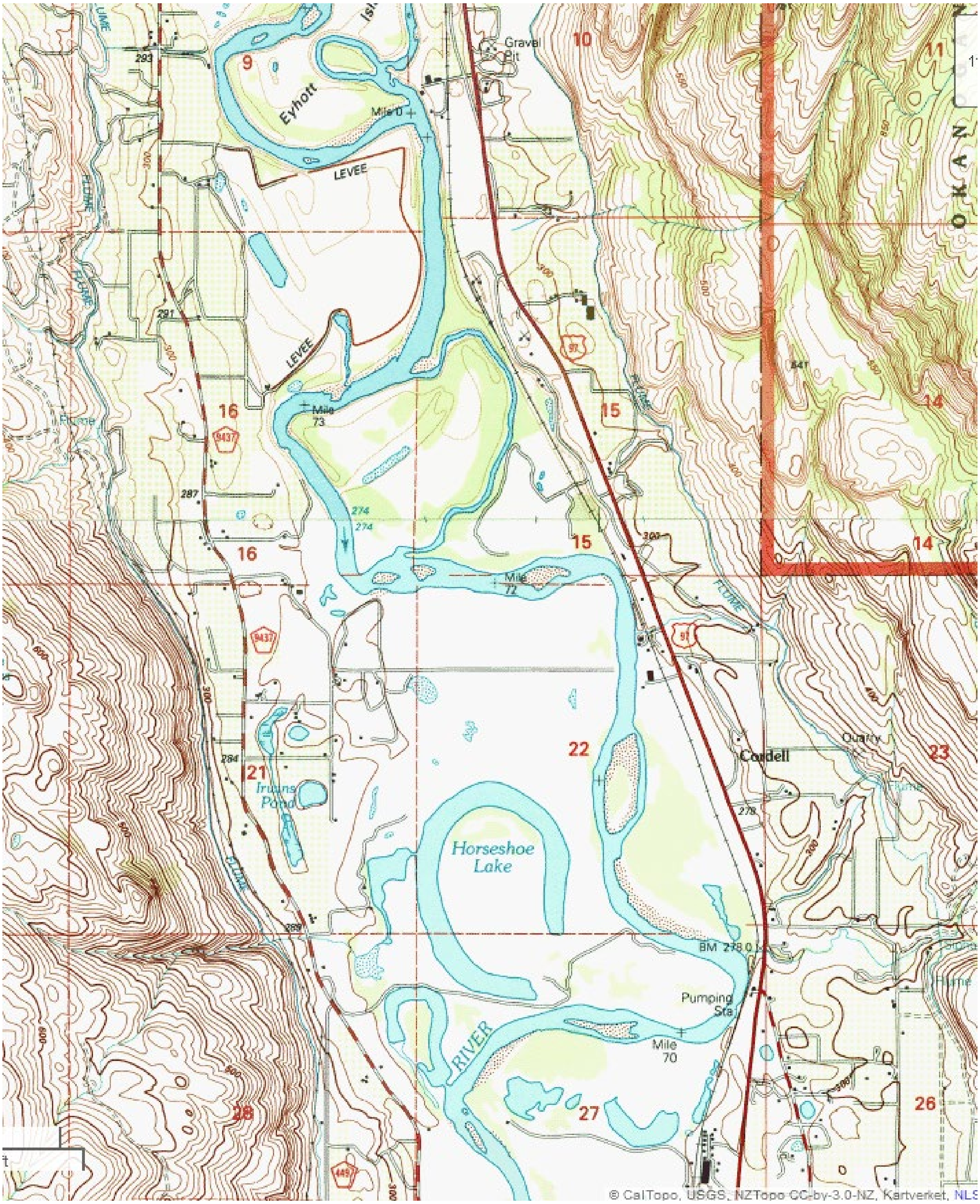

Figure 4. Topographic map view of sinuous nature of the Okanogan River south of Oroville. Note the classic horseshoe lake, aptly named "Horseshoe Lake". From Caltopo.com.

Tonasket to Molson Grade

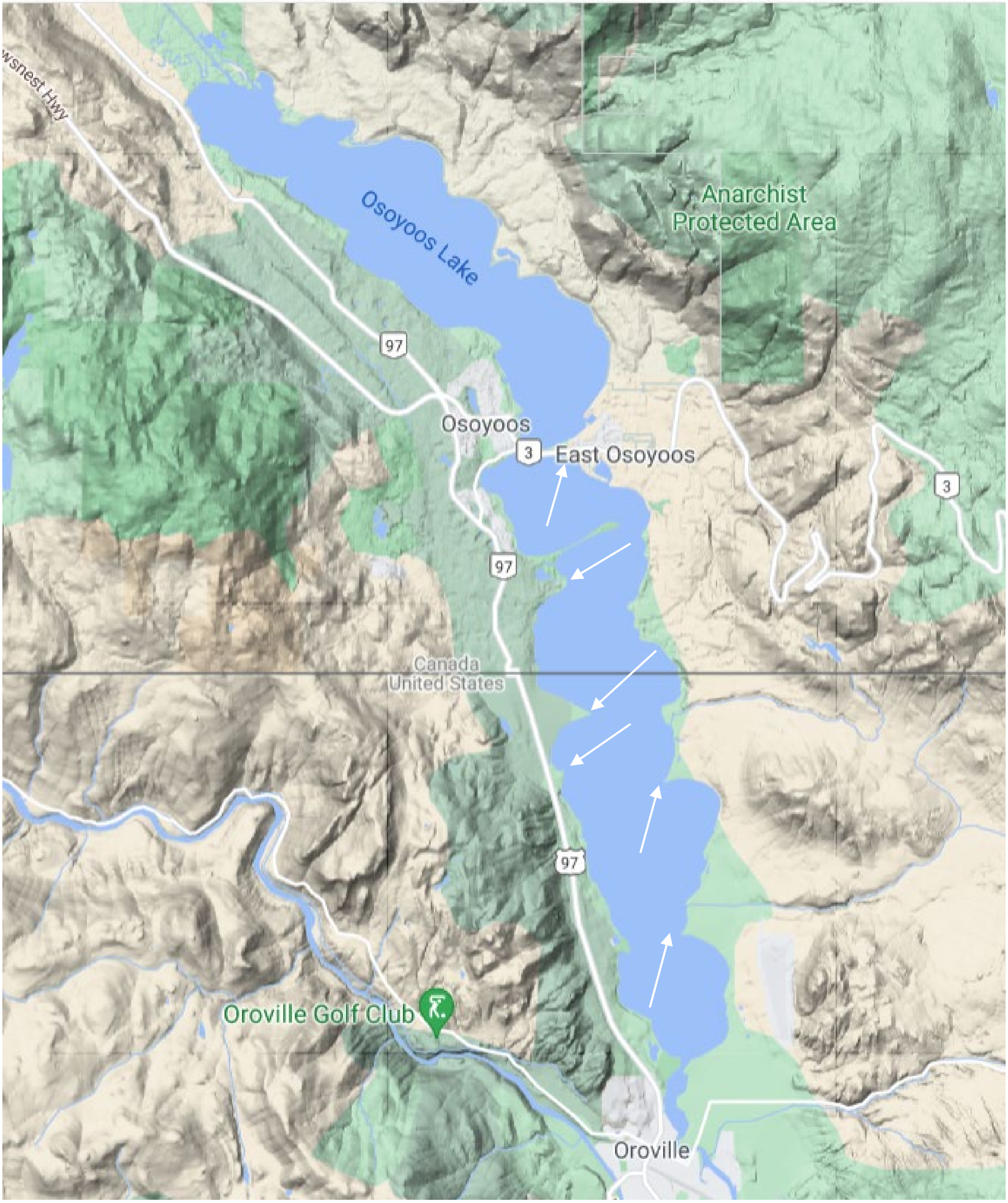

Figure 5. Map view of southern Lake Osoyoos and its numerous cuspate spits (examples indicated with arrows). From Google Earth.

Stop 1—Lower Molson Grade

Location: We are located at a pullout on the lower Molson Grade (**Figure 6**).

Types of glaciers: The Okanogan Highlands were glaciated during the *Pleistocene* (2.2 million years ago to about 11,500 years ago) by two different types of glaciers—massive *ice sheets* and small *cirque glaciers*. The ice sheet evidence is by far the most prevalent and that will be much of our focus today. At one of our later stops we will explore the evidence for cirque glaciation.

Cordilleran Ice Sheet: The ice sheet that covered this area was known as the Okanogan Lobe of the Cordilleran Ice Sheet. According to evidence from southern British Columbia, there appear to have been two major ice sheet glaciations in the late *Pleistocene*. Because glaciers mostly obliterate landscapes over which they slide, there is little evidence of the earlier glaciation. Therefore, much of what we see will see today is likely the result of the last glaciation accomplished by the Okanogan Lobe. This ice sheet originated in the Monashee Mountains of northern British Columbia (**Figure 7**) and advanced to the south beginning about 25,000 years ago (Roed, 2011a). It reached its maximum southern extent about 85 miles south of here on the Waterville Plateau near the little village of Withrow. By about 15,400 years ago, it was retreating from its maximum extent (Balbas & others, 2017), and had retreated to the Malott area in the southern Okanogan Valley by ~13,410-13,710 calendar years before present (Porter, 1978; Kuehn & others, 2009). At its maximum, the Okanogan Lobe towered over this landscape. It has been estimated that the ice was 6,300 feet thick over the present-day site of Oroville (Daly, 1912). As the ice melted, the high areas became ice free first resulting in sediment-laden water running off the highlands into the lowlands dammed by the Okanogan Lobe (**Figure 8**). The impoundment of the runoff created glacial lakes in many of the side valleys. This history can be seen in the landforms and sediments along the lower Molson Grade.

Glacial lake sediments and till: The outcrop at this stop shows two types of glacial sediments each with an important story to tell. The lowermost sediments are bedded silts and clays indicative of quiet water deposition (**Figure 9**). Roed (2011b) interprets them as being deposited in Glacial Lake Oliver, a lake that extended from southern British Columbia to Ellisford. Glacial lakes may form from dams created by *end moraines* (i.e., piles of debris deposited at the terminus of glacier) or by ice. They may also form from isostatic depression of Earth's crust by the mass of the glacial ice.

Stop 1—Lower Molson Grade

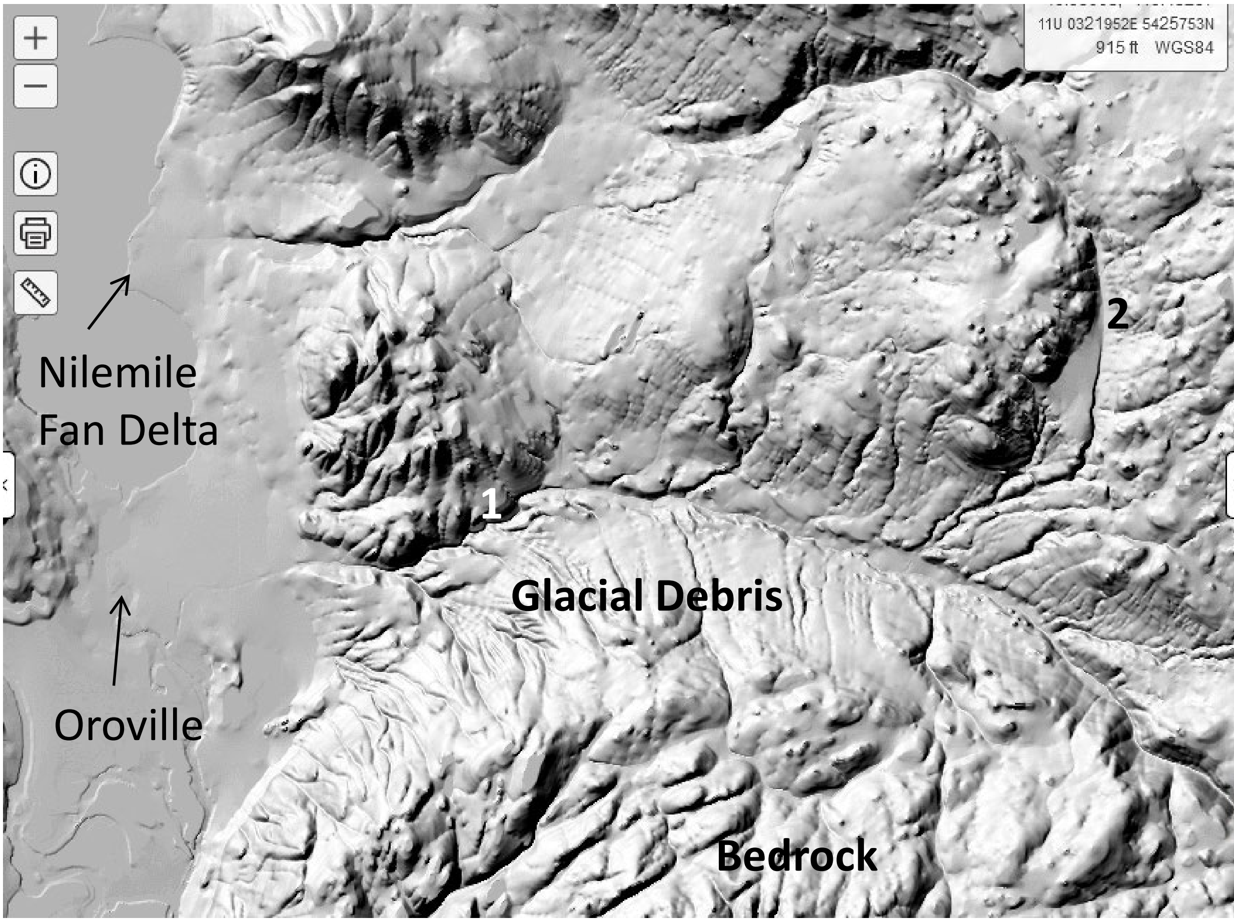

Figure 6. Shaded relief map view of terrain at Stops 1 & 2. Note the ~smooth nature of glacial debris-covered terrain as opposed to the more irregular nature of the bedrock surface. Bold numbers indicate field trip stops. From Caltopo.com.

Stop 1—Lower Molson Grade

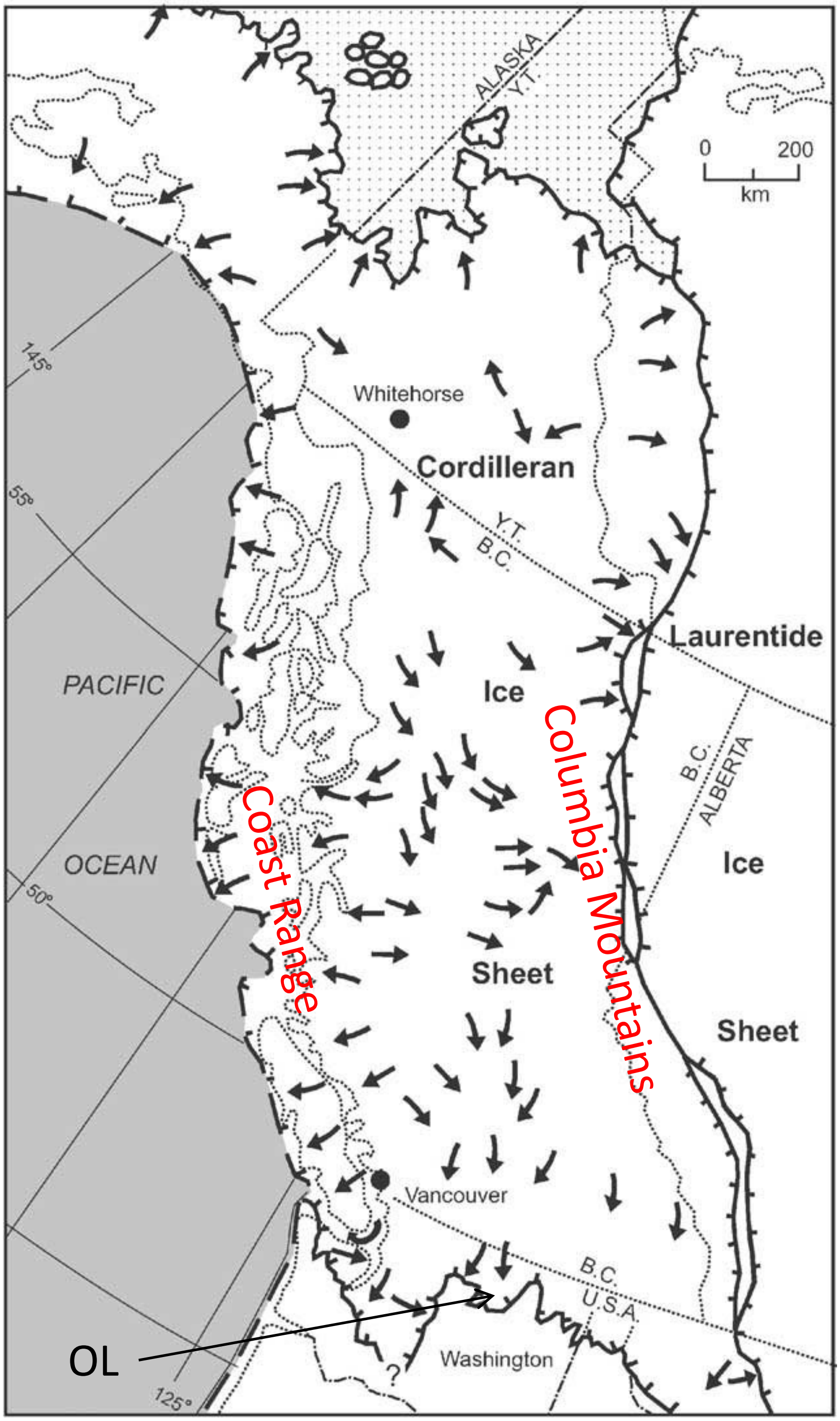

Figure 7. Map view of Cordilleran Icesheet. Okanogan Lobe is indicated by an arrow and OL. From Clague and James (2002).

Stop 1—Lower Molson Grade

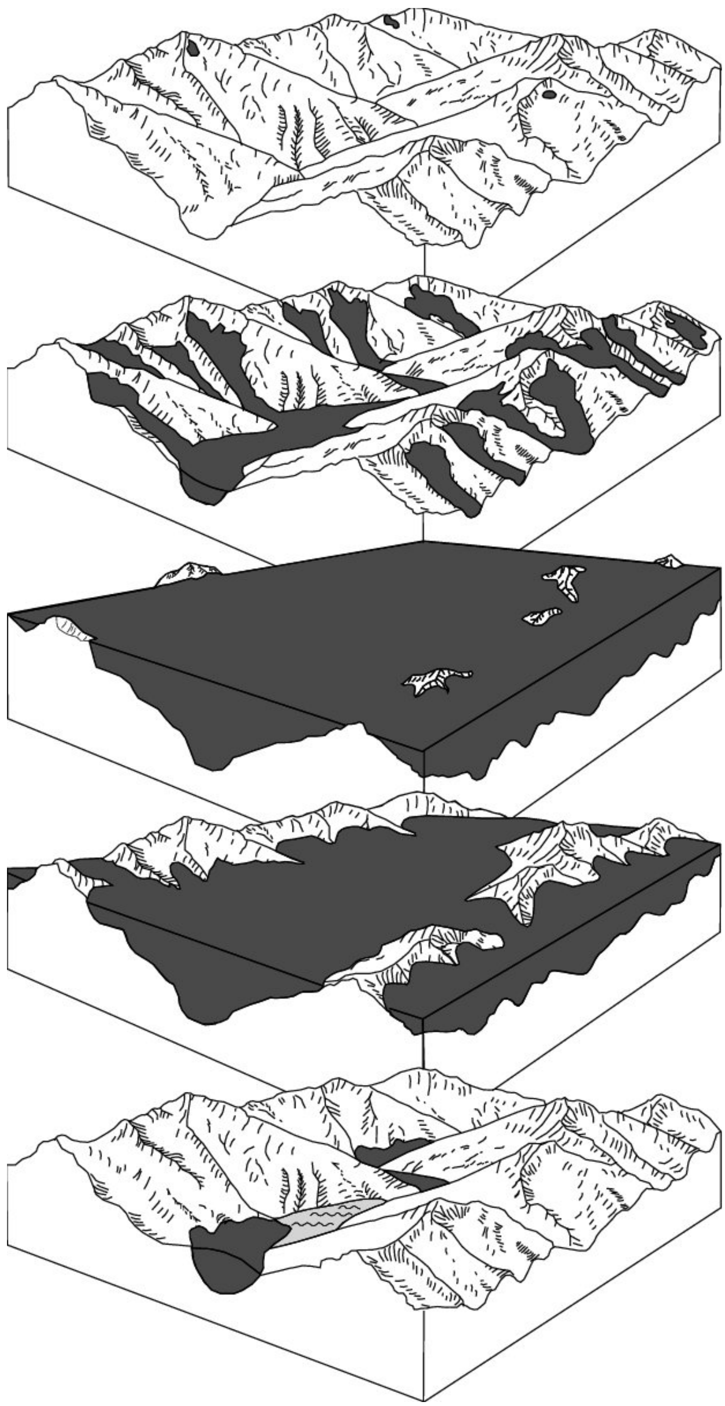

Figure 8. Block diagrams showing nature of likely advance and retreat of Okanogan Lobe in mountainous terrain. From Clague and James (2002).

Stop 1—Lower Molson Grade

Glacial lake sediments and till: (continued)…In the case of Glacial Lake Oliver, hummocky deposits near Ellisford may be remnants of an end moraine that blocked the Okanogan Valley therefore impounding ice sheet meltwater as a lake (Roed, 2011a). Conversely, if the lake deposits were confined solely to the Tonasket Creek Valley, an ice dam origin would be more likely. Glacial Lake Oliver sediments are as thick as 560 feet in places suggesting the lake was at least that deep (Roed, 2011a). However, we don't know the age of the sediments.

Overlying the glacial lake sediments are unsorted silts to boulders (**Figure 9**). These jumbled deposits are characteristics of glacial till, the sediments directly deposited by glacial ice. Because they are atop the Glacial Lake Oliver sediments, they were deposited after. This suggests that the Okanogan Lobe advanced over Glacial Lake Oliver and subsequently retreated. We don't know if this advance was the primary advance toward the maximum extent on the Waterville Plateau or if it was a readvance by the Okanogan Lobe during the general retreat of ice.

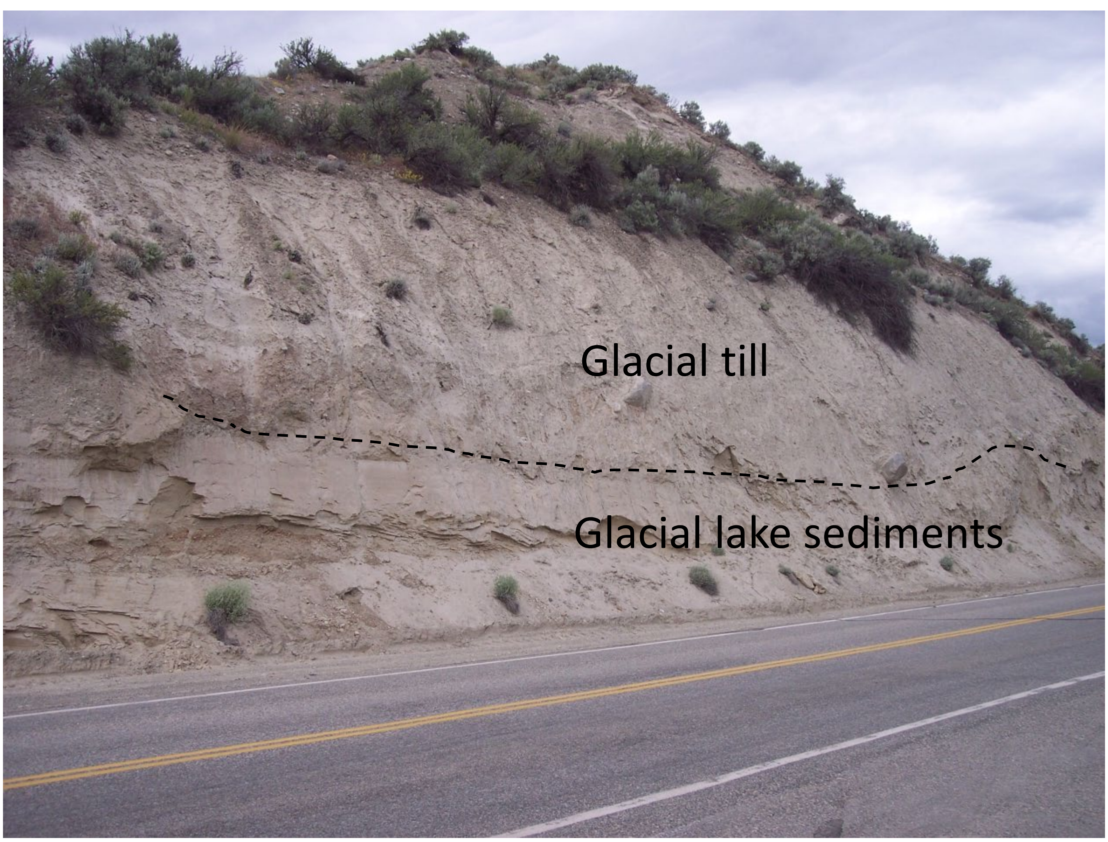

Figure 9. Side view of Lower Molson Grade roadcut. Note the fine textured and bedded glacial lake sediments overlain by a boulder and fine sediment mix of till. Author photo, May 2022.

Lower Molson Grade to Ninemile Road

The route from here…: From Stop 1, we will continue up the Molson Grade on the Chesaw Road for about 3.5 miles. Upon reaching Ninemile Road, turn left onto that gravel road and continue for about 3.5 miles. At that point, pull over to the side of the road and park. You should be across the valley from a large gray house and should be just down grade from the third roadcut through bedrock. GPS coordinates are: 48.969005° N, 119.308905° W.

Oroville to Spokane Line: Much of our route on Ninemile Road is on the long abandoned Oroville to Spokane railroad line, a spur of the Great Northern Railroad. The route of this railroad had numerous switchbacks so the locomotives could negotiate the ~2800 foot elevation difference between Oroville and Molson (**Figure 10**). This railroad ran from 1906 to 1932 (Kirk and Alexander, 1990).

Figure 10. Map view of route of Oroville to Spokane Line, 1906-1932 (shown with white line). Bold numbers indicate approximate locations of field trip stops. Route interpreted from Google Earth Pro image.

Stop 2—Ninemile Road

Location: We are located along Ninemile Road overlooking a dry valley to our west.

Ninemile fan delta: Like alluvial fans, *fan deltas* are fan-shaped (like a fan you would wave in front of your face to cool down) landforms but are deposited into standing water. They are common features of relict glacial lakes. We are standing above the Ninemile Fan Delta, a deposit more than 0.75 mile long. So…what makes this a fan delta? First, note the elongate fan shape on **Figure 11**. Second, the smooth (and relatively flat) surface of the delta tells us that the feature formed in a relatively static body of water. Third, the steep downstream end of the delta tells us that sediments dropped out rapidly when the stream flowed into standing water. I would expect that the fan delta is composed of layered gravel and sand, intermixed with layers of finer lake sediments. The fan delta tells us that Glacial Lake Oliver extended up to this point. This supports Roed's (2011a) data that showed that Glacial Lake Oliver was potentially 560 m deep! If we encounter glacial lake sediments above this point, they should be associated with very local, small glacial lakes. Meltwater or perhaps post-glacial streams eroded the channel immediately below us and along the edge of the fan delta.

Ninemile Grade to Molson

The route from here…: We continue up Ninemile Road about 7.0 miles to Molson. Nearly all of the route to Molson follows the Oroville to Spokane Rail Line railbed. As we near Molson, we pass very near the International Boundary. Park at the Molson School. GPS coordinates are: 48.978844° N, 119.201530° W.

Stream capture. As we ascend Ninemile Road, we follow the drainage that once formed the Ninemile Fan Delta. Just north of where Ninemile Road intersects with Point Drive, this drainage is cutoff or *captured* by the present-day Ninemile Creek valley. This suggests Pleistocene drainage from this area flowed south into the Tonasket Creek drainage. However, with the retreat of the Cordilleran Icesheet, Ninemile Creek eroded a channel that continued more westward, likely because of steeper gradient. This drainage dumped directly into Lake Osoyoos forming a large fan delta (**Figure 6**).

Stop 2—Ninemile Road

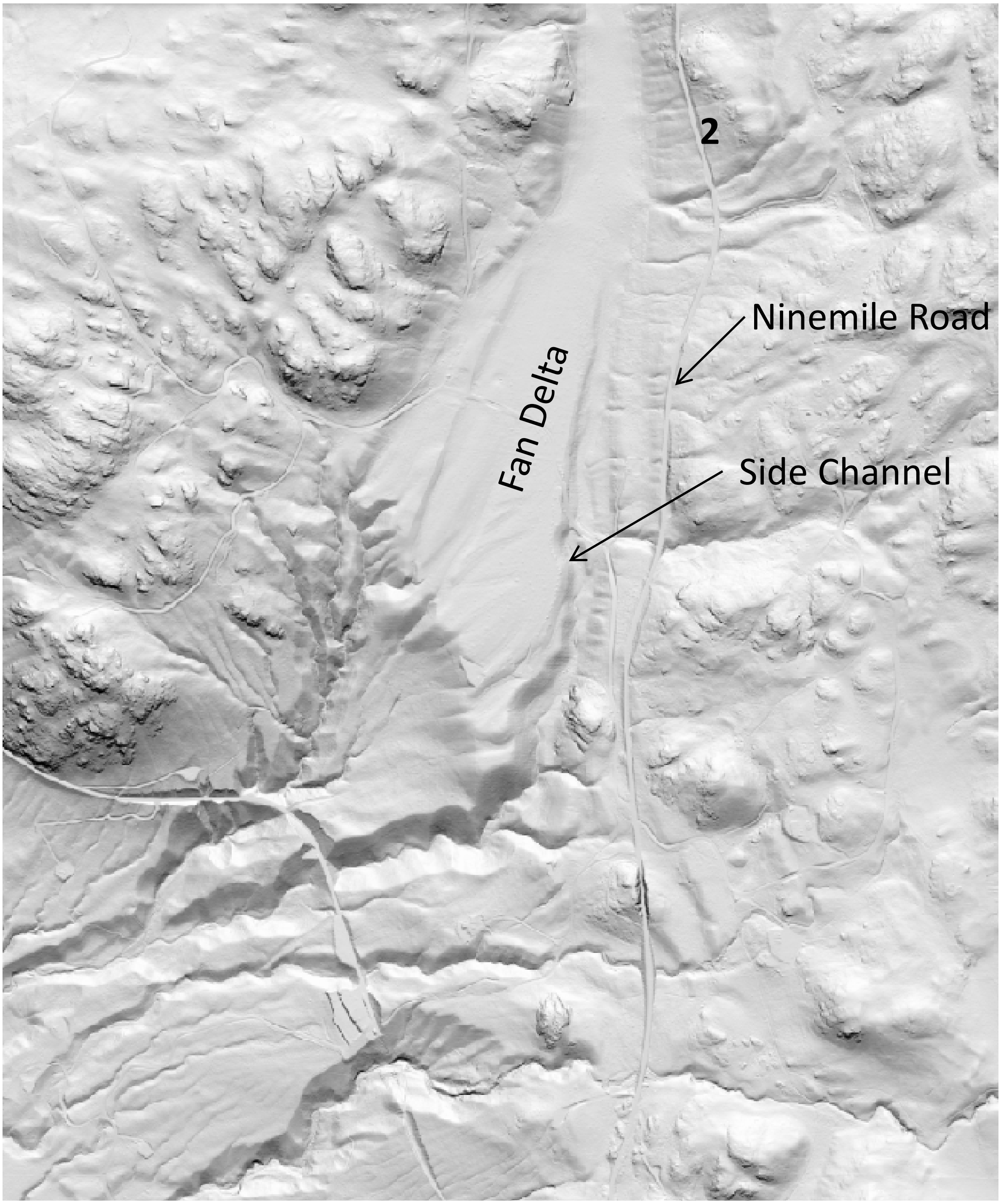

Figure 11. LIDAR image view of large fan delta along Ninemile Road. Note ~fan shape, smooth surface, and abrupt, downstream end. Also, note side channel that likely post-dates fan delta formation. Bold 2 is approximate location of Stop 2. From Washington state LIDAR portal.

Stop 2—Ninemile Road

Figure 12. View southwest at Ninemile fan delta from Ninemile Road. Author photo, May 2022.

Ninemile Grade to Molson

Rolling topography: The topography of the route is very characteristic of that shaped beneath ice sheets—rounded, smoothed, and often covered with lakes. This is mostly an erosional landscape—i.e., the ice sheet mostly eroded the bedrock here. The result of this erosion is not only the rounded and smoothed surface but also a general lack of soil here. This geologic heritage, combined with cool climate (due to high elevation) limit the viability of agriculture, especially farming. However, farming has been practiced here for more than a century. You can see evidence of past farming in the farmer-stacked rock piles in now grass pastures. Actively farmed fields are present closer to Sidley Lake.

Stop 3--Molson

Location: We are located at the historic Molson School (**Figure 13**). Enjoy the museum restrooms, your lunch, and the museum exhibits. Please thank the museum with a $ donation. We will gather as a group about 30 minutes after arriving here.

Climate. Molson is located at approximately 3,700 ft elevation. This relatively high elevation results in a vastly different climate than that of Oroville at ~925 feet on the floor of the Okanogan Valley—i.e., temperatures are lower and precipitation is higher in Molson (**Figure 14**). The average annual temperature here is about 41ºF, and average total precipitation is about 19 inches/year.

Glaciers, lakes, and streams. Glaciers are notorious for altering streams and creating lakes. Glacially-derived stream alterations include blocking stream valleys and changing stream routes. We have seen evidence of the former in the Ninemile Creek drainage. Both actions appear to have occurred here. Lakes are common features of glaciated landscapes. Molson and Sidley lakes likely formed in shallow depressions in deposits left by the Okanogan Lobe (**Figure 12**). Therefore, these lakes are relatively geologically young features on the landscape. Because the glacial deposits are shallow, the lakes are shallow as well (e.g., Sidley is 22 ft deep—Wolcott, 1964). Two odd features characterize these lakes and their settings.

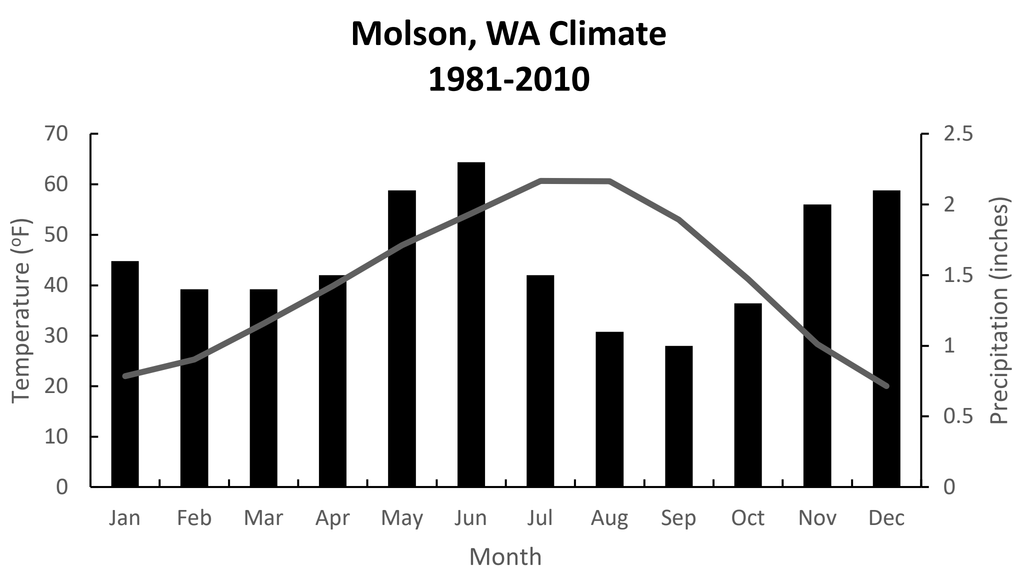

Figure 14. Climograph for Molson based on data from 1981-2010. Temperature shown as a line graph and precipitation depicted as bars. Source: PRISM climate site.

Stop 3—Molson

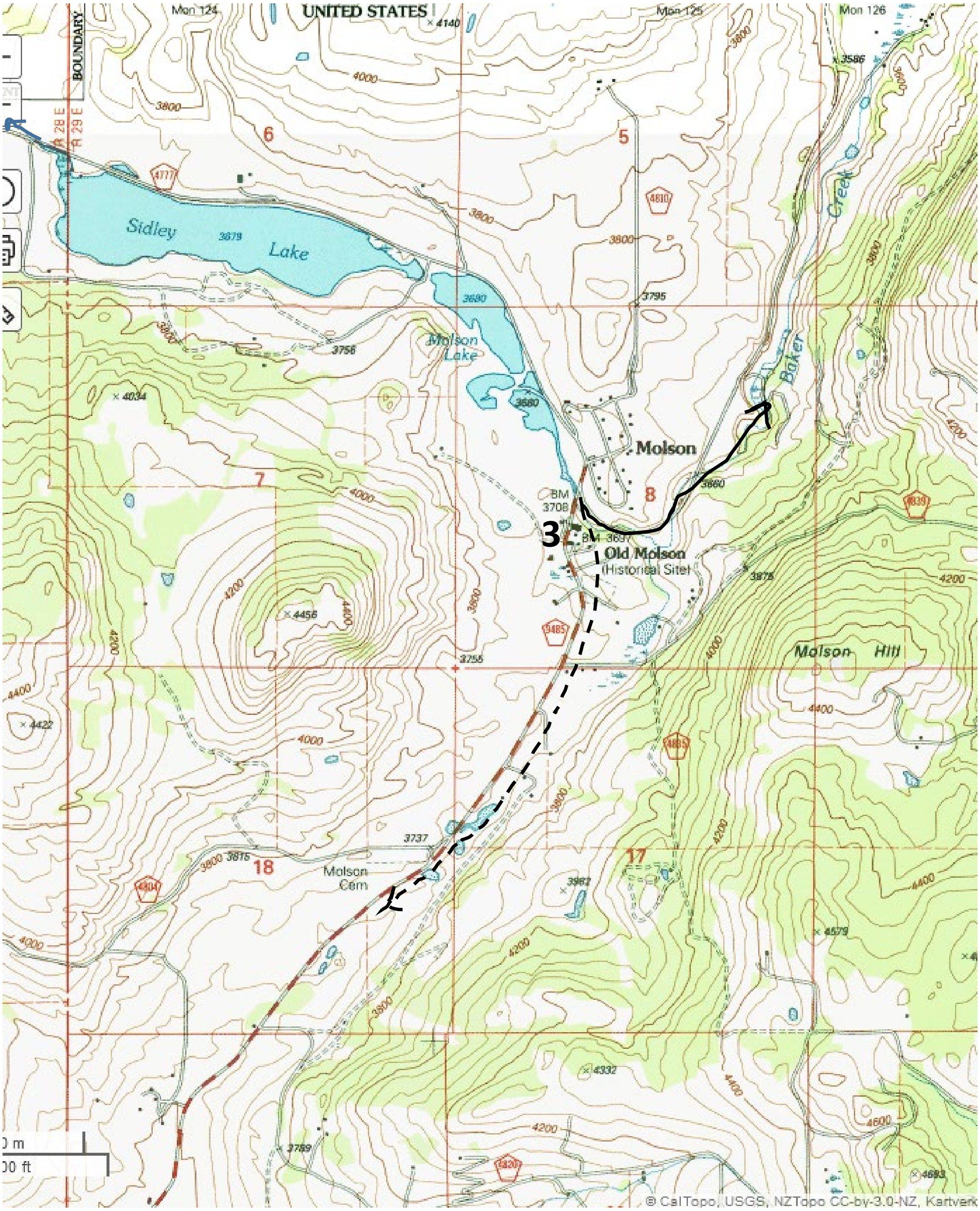

Figure 13. Topographic map view of the Molson area. Dashed arrow indicates former route of Baker Creek. Solid arrow indicates current path. Bold 3 indicates approximate location of Stop 3. U.S. Geological Survey map from Caltopo.com.

Stop 3--Molson

Glaciers, lakes, and streams. (continued)…First, the lakes occupy opposite sides of a drainage divide despite only being separated by tens of feet! At high levels, Sidley Lake's outlet flows into Ninemile Creek (**Figure 13**) which proceeds into British Columbia then back into Washington state and into Lake Osoyoos near Oroville. Sidley Lake flows into Baker Creek (**Figure 13**), which in turn, flows into British Columbia and is tributary to the Kettle River at Rock Creek. The Oroville to Spokane Railroad followed this route (**Figures 10 & 13**). It is rare in terrain other than that shaped by ice sheets to find such a drainage divide situation. The other odd feature here is the >90^o bend that Baker Creek makes at Molson to flow to the northeast (**Figure 13**). Sharp stream bends suggest some kind of structural effect (e.g., stream follows a fracture or fault in bedrock) or perhaps landslide or alluvial fan deposit that has disrupted the stream pattern. In this case, deposition of about 40 feet of glacial sediments appears to have been sufficient to cause the stream bend. Prior to the end of the last glaciation, I will bet that Baker Creek flowed south from Molson through Mud Lake Valley. This means that Baker Creek ultimately reached the Okanogan River via Tonasket Creek.

Rounded terrain. Note the large hills to the west and east of here. All are rounded. This is a characteristic of glacially eroded landscapes, and it is prevalent in the Okanogan Highlands—i.e., there are no craggy peaks here like you will find in the Cascade Range to the West. This is because the Cordilleran Icesheet overrode this entire landscape. We will talk more about this at Stop 5.

Molson to Middle Mary Ann Creek

From here to there…: From Molson, head south for less than a half mile and turn east (left) onto gravel Molson Summit Road (USFS road 4839). Follow this road for about 3.0 miles over the north shoulder of Molson Hill and into the upper Mary Ann Creek drainage. At a fork in the road at about the 3.0 mile mark, take the left fork (USFS 4839 or Mary Ann Creek Road). Follow this for another ~3.0 miles to a Washington State Department of Fish and Wildlife site on middle Mary Ann Creek. An old, abandoned house sits at the site. There is off-road parking here but it's a steep incline to get into it. Instead, you may choose to park along the road. Park along the side of the road there. GPS coordinates are: 48.957180°N, 119.100846° W.

More possible drainage changes: As we descend USFS road 4839, our road and Mary Ann Creek bends to the left (east). Another road (USFS 4825) and a mostly dry valley continue south. I suspect that this valley was once occupied by Mary Ann Creek but was shifted because of the deposition of glacial sediments.

Stop 4—Middle Mary Ann Creek

Location. We are located at a Washington State Fish and Wildlife site along USFS road 4839 in the middle Mary Ann Creek Valley southeast of Molson (**Figure 15**).

Stagnant ice features. Glaciers may sit in one place and waste away, especially atop gentle topography and as they get thinner. We refer to this as stagnating. The results are *stagnant ice deposits*. The first clue to stagnant ice is the *hummocky* (i.e., up and down) nature of the landscape. Hills are round to elongate and separated by depressions. *Kames* (round hills) and *eskers* (sinuous ridges) are common landforms of stagnant ice terrain, and are classic examples of subglacial *inverted topography* —i.e., they formed from deposition of sediment into depressions or cavities in the ice. When the ice melted, these depressions or cavities became hills and ridges (**Figure 16**). Further, the eskers appear to overlap here suggesting that they were deposited at different times. The kames and eskers on middle Mary Ann Creek are phenomenal (**Figures 17 & 18**)! They indicate that the Okanogan Lobe must have stagnated here for a significant amount of time. These features have previously been identified in this area by Phetteplace (1954), Moen (1980), and Hruska (2018).

Terraces and terracettes: Note the series of terraces west and south of us (**Figures 15 & 18**). Previous researchers have also noted these features in this vicinity (Phetteplace, 1954), Moen, 1980, and Hruska , 2018). Given stagnant ice terrain and what that suggests about deposition of glacial meltwater sediments, it makes sense that the Mary Ann Creek Valley was filled with sediment deposited by glacial meltwater as the Okanogan Lobe melted. Later incision by Mary Ann Creek left terraces of glacialfluvial sediments. Multiple periods of incision are indicated by the multiple terraces. Conversely, the ample sediment associated with glacial meltwater could be concentrated along the sides of glacial ice occupying valley floors. In this case, when the glacial ice melted, it would leave behind kame terraces (**Figure 16**).

Small terraces (i.e., *terracettes*) mantle the risers of terraces as well as the steep slopes of eskers and kames. Some have attributed these to cattle and sheep movements on the slopes while others hypothesize that they form from the very slow flow of sediments on steep slopes. They may also work together, especially if animals are grazing on soggy wet slopes. Whatever the cause, what we see are likely geologically recent phenomena.

Stop 4—Middle Mary Ann Creek

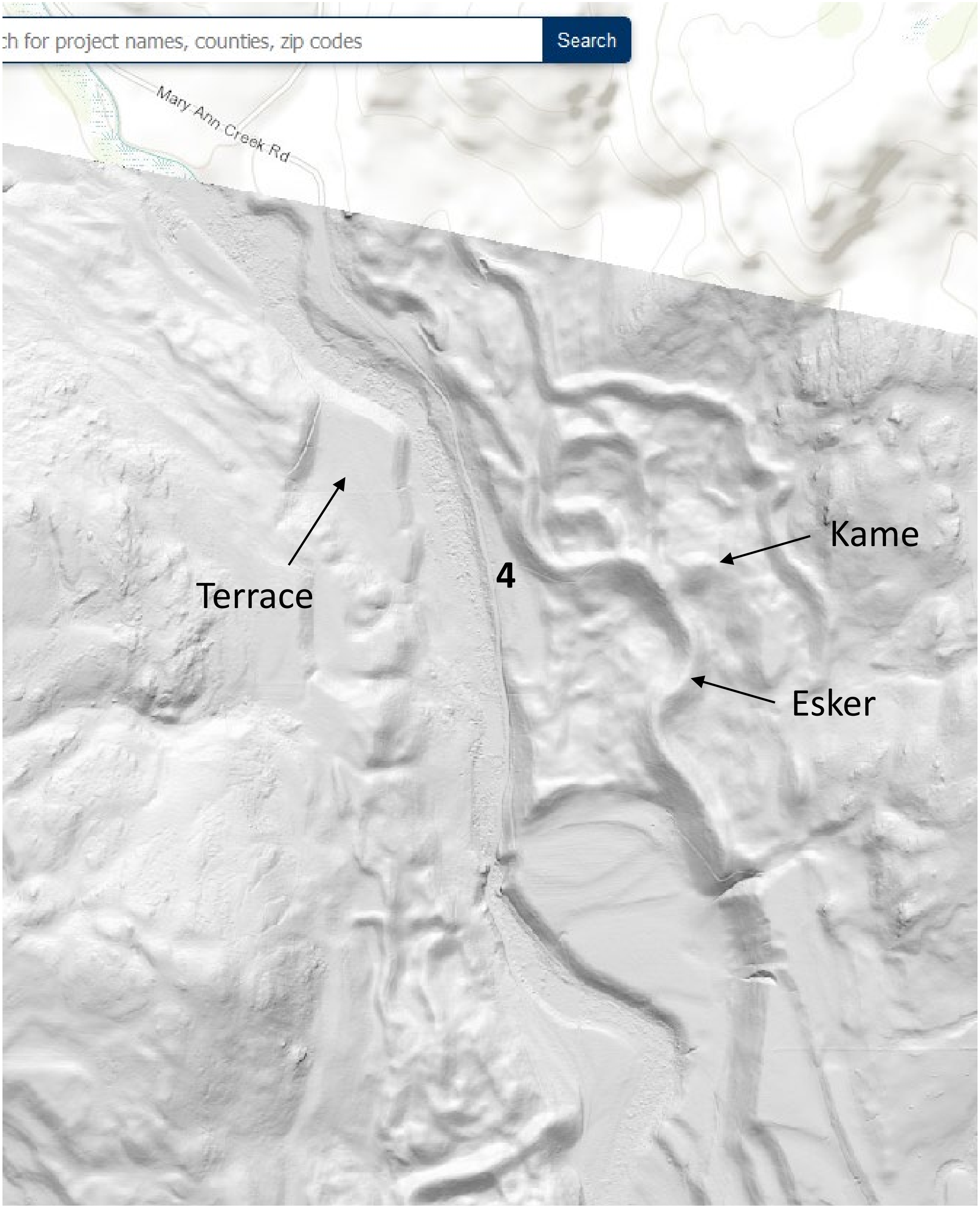

Figure 15. Vertical overhead LIDAR view of the stagnant ice features in the middle Mary Ann Creek Valley. Bold number is the approximate location of Stop 4. Source: Washington LIDAR Portal.

Stop 4—Middle Mary Ann Creek

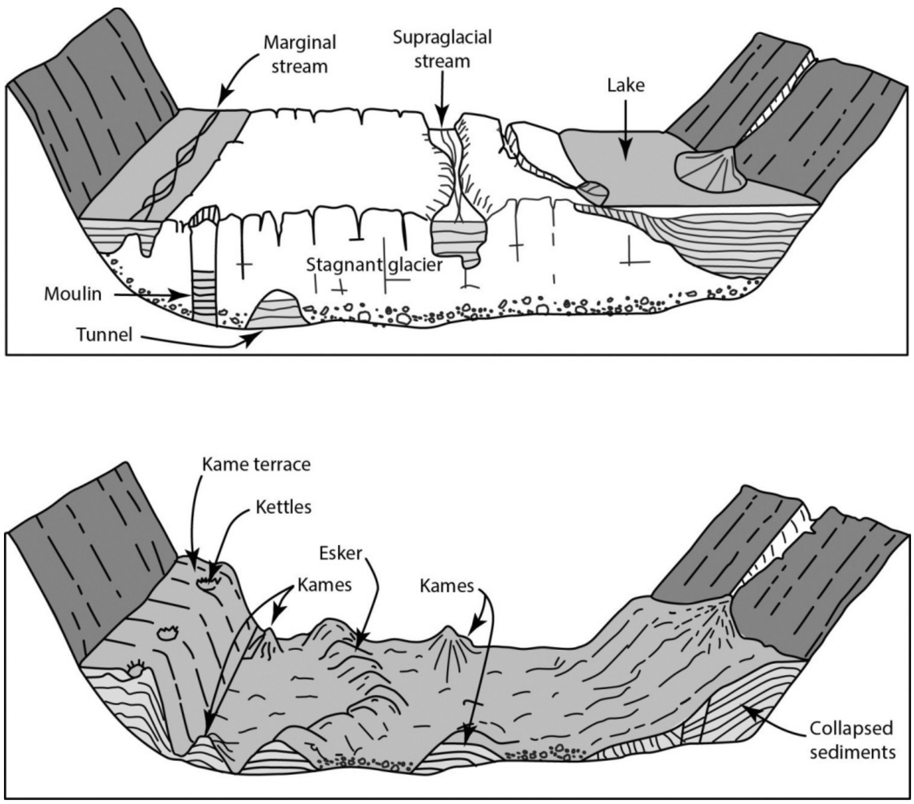

Figure 16. Model of esker, kame, kettle, and kame terrace formation. From https://gq.mines.gouv.qc.ca/lexique-stratigraphique/quaternaire/kame-et-kettle_en/

Okanogan Highland soils: Soils reflect the parent material (i.e., bedrock and sediments), climate, vegetation, topography, time, and land use of the area of their formation. Diverse landscapes result in diverse soils. Such is the case in the Okanogan Highlands. One aspect of soils that is particularly interesting is the amount of black to dark brown, organic material in these soils. The soils of the ample Highlands meadows are generally organic-rich because of the abundant grass roots associated grasslands. Such soils are terms *mollisols* and they are the mapped soils of the crests and steep slopes of the eskers and kames here (e.g., Chesaw Series). Another interesting aspect of Highlands soils is that they often contain ample Glacier Peak *tephra* (i.e., volcanic ejecta). That tephra weathers to particular types of clays which bond well with soil organic matter. The resulting deep, dark soils are termed *andisols* and they are present at the bases of the steep slopes here (e.g., Koepke Series).

Stop 4—Middle Mary Ann Creek

Figure 17. Esker covered with balsamroot, middle Mary Ann Creek. Author photo, May 2022.

Figure 18. Terraces on the west side of the middle Mary Ann Creek valley. Author photo, May 2022.

Stop 4—Middle Mary Ann Creek

Figure 19. Beaver dams (indicated by white arrows) and associated ponds along middle Mary Ann Creek. Bold 4 indicates location of Stop 4. Google Earth Pro image, April 9, 2016.

Beavers and beaver dams: Middle Mary Ann Creek is dammed in many places by beaver dams (**Figure 19**). While beavers and beaver dams may cause problems (e.g., killing wanted trees, flooding property) they are often viewed as being very positive in a landscape sense. In this landscape of highly erodible sediments, the ponds behind beaver dams are great places to collect those sediments. Beaver dams, therefore often result in the in-filling of deeply incised channels and are very useful in the healing of damaged watersheds. When beaver dams break and are not repaired, ponds turn into wetlands which, in turn, become ~flat floored meadows known as *beaver meadows*. Much of middle Mary Ann Creek's valley floor consists of beaver meadows.

Middle Mary Ann Creek to Knob Hill

From here to there…: Continue down the Mary Ann Creek Road for another 2 miles to its junction with the paved Oroville-Chesaw Road. At this junction, turn right (west) and drive about 0.75 miles to the junction of the Oroville-Chesaw Road with the Hungry Hollow Road. Turn left (south) onto Hungry Hollow Road and follow it about 6 miles to its junction with the Tonasket-Havillah Road. Turn left onto the Tonasket-Havillah Road and follow it about 1.0 mile to the short, gravel, cutoff road to Nealey Road. We will park here. GPS coordinates are: 48.856772°N, 119.167019° W.

Place names: We follow Hungry Hollow Road for some of the drive from middle Mary Ann Creek to Knob Hill. What is the origin of such a name, and what do names tell us about a landscape (**Figures 20 & 21**)? A query to OHA's Jen Weddle came up with the following: *Hungry Hollow seems to have been named sometime between 1934 and 1959 (when that name first appears on a Mesker Map)… It is a tough place to scratch out a living, and it's a hollow…An excerpt from an article by Lela Turner, a former Tonasket Elementary School teacher, stated "...Hungry Hollow near Chesaw (so named in the early days because all it's inhabitants were bachelors)...".*

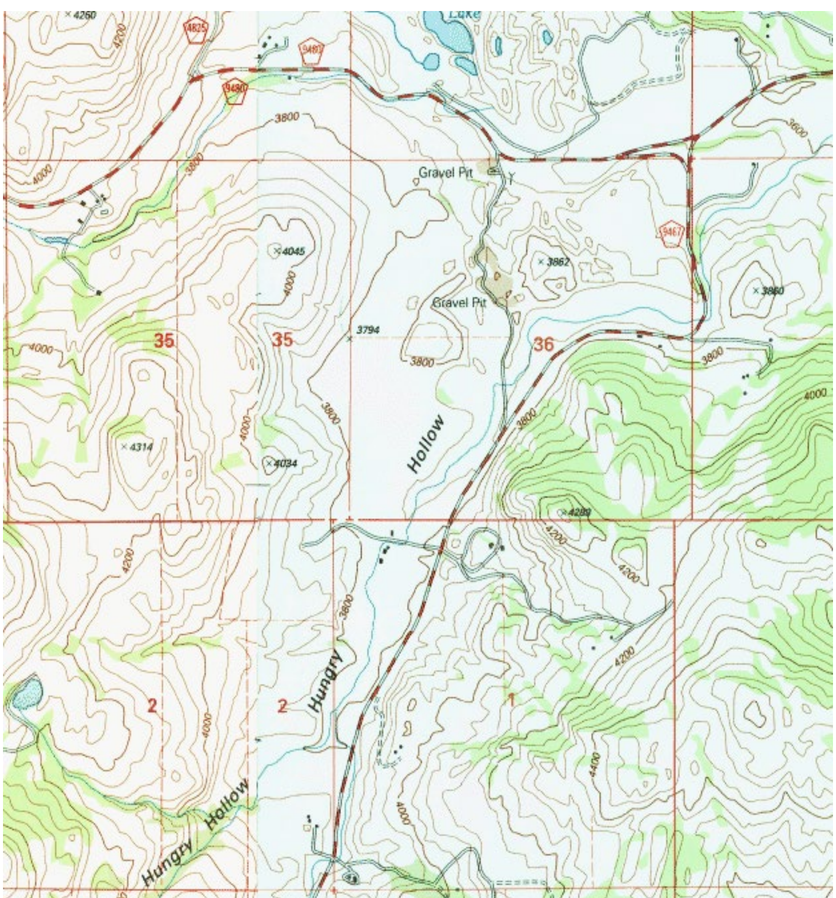

Figure 20. Topographic map view of Hungry Hollow. From Caltopo.com.

Middle Mary Ann Creek to Knob Hill

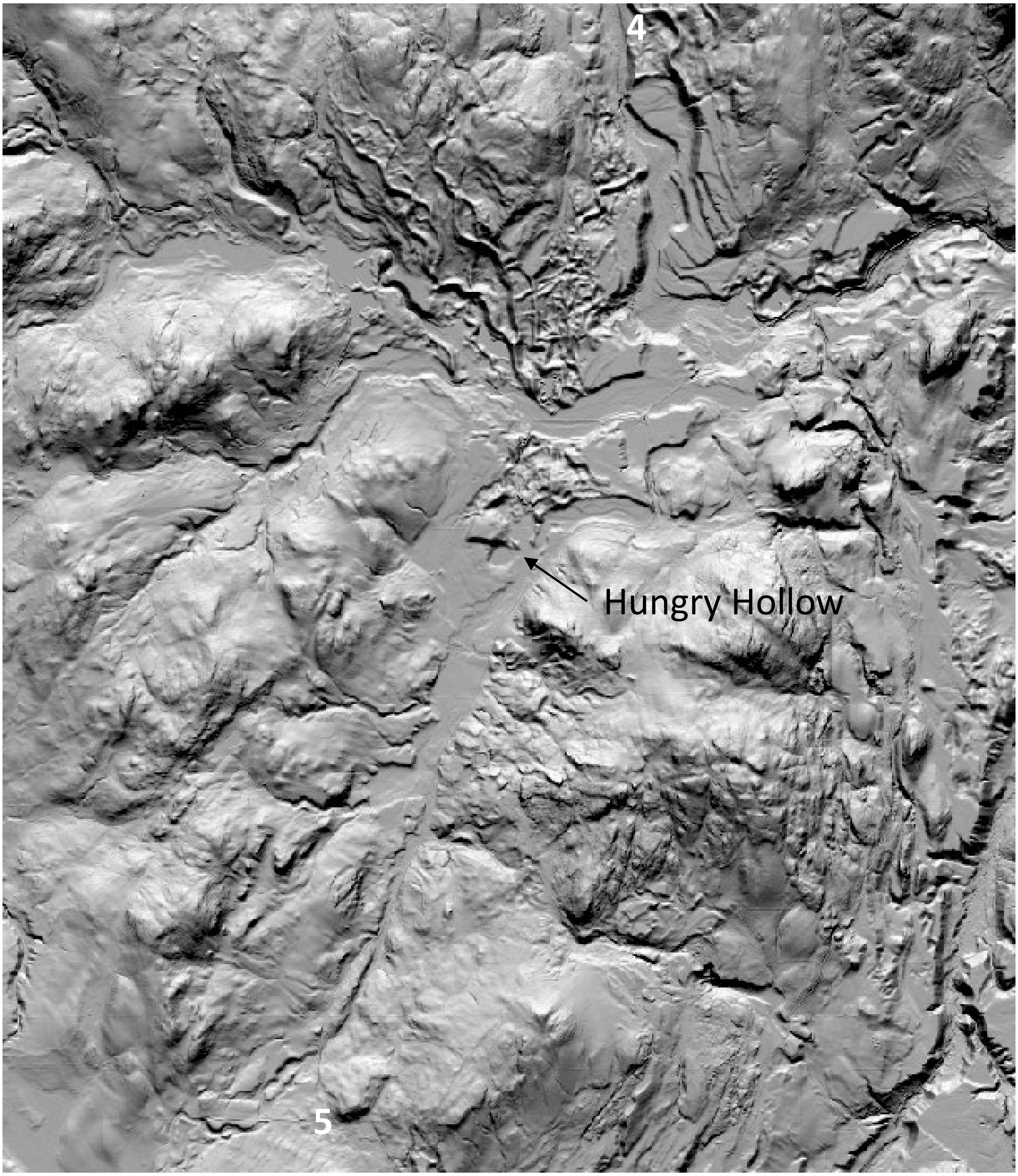

Figure 21. LIDAR image of the landscape from Middle Mary Ann Creek to Knob Hills. Bold numbers indicate Stops 4 and 5. Note rounded but irregular bedrock knobs that were sculpted by the Okanogan Lobe. Also, note the smoother valley floors characterized by glacial deposition. From Washington state LIDAR Portal.

Stop 5—Knob Hill

Location. We are located at the south end of Knob Hill about 0.5 miles south of Sitzmark Ski Area (**Figures 21 & 22**). Our view is toward the Havillah area and Mt. Bonaparte.

Glacial Erosion. Much of the terrain in this portion of the Okanogan Highlands attests to the effects of glacial erosion. We can see this with the abundant exposed, rounded bedrock outcrops with thin covers of soil. It is partially this lack of soil that limits crops to valleys here. Another result of glacial erosion is the common orientation of bedrock knobs. In this area, the knobs are aligned to the south southwest. Knob Hill, home of Sitzmark Ski Area, is one such aligned hill. Note from **Figure 24** that Knob Hill is steeper on the south than on the north. Because of this asymmetry and its bedrock composition, we call Knob Hill a *roche moutonee* . The shape is a result of glacial *abrasion* on the uphill (or stoss) side and *plucking* on the downglacier (or lee) side (**Figure 23**). The orientation of Knob Hill tells us that the ice that sculpted it was moving to the southwest (**Figure 24**).

Alpine Glaciation in the Highlands. Mt. Bonaparte lies to the southeast of us. At 7,257 ft elevation, it is the highest mountain in the Okanogan Highlands. Glacial erratics on the summit of Mt. Bonaparte tell us that the Cordilleran Icesheet overtopped its summit. And if Mt. Bonaparte was covered by the ice sheet all other summits must have been as well. However, some researchers have suggested that the peaks and overall highlands would have melted out first during glacier recession because the ice would be thinner there. As a result, some of the higher peaks were exposed to the atmosphere during glacier recession. Either when the climate was colder but the icesheet had not yet reached the area, or during a cold episode during glacier recession, *cirque glaciers* formed on the north face of Mt. Bonaparte. Cirque glaciers form in *cirques*—i.e., amphitheater-shaped basins that favor the collection of snow. Cirque glaciers, like icesheets, depend on low temperatures and ample snowfall. In the northern hemisphere, they commonly form on north-facing slopes where temperatures are lower. I have identified at least two cirques on the north face of Mt. Bonaparte (**Figures 25 & 26**). The meltwater from these would have drained directly into Antoine Creek. This runoff, combined with copious meltwater from the Okanogan Lobe, may explain the Antoine Creek "gorge" (see Stop 6).

Stop 5—Knob Hill

Figure 22. View south from Tonasket-Havillah Road toward Sitzmark and the steep south end of Knob Hill. Author photo, May 2022.

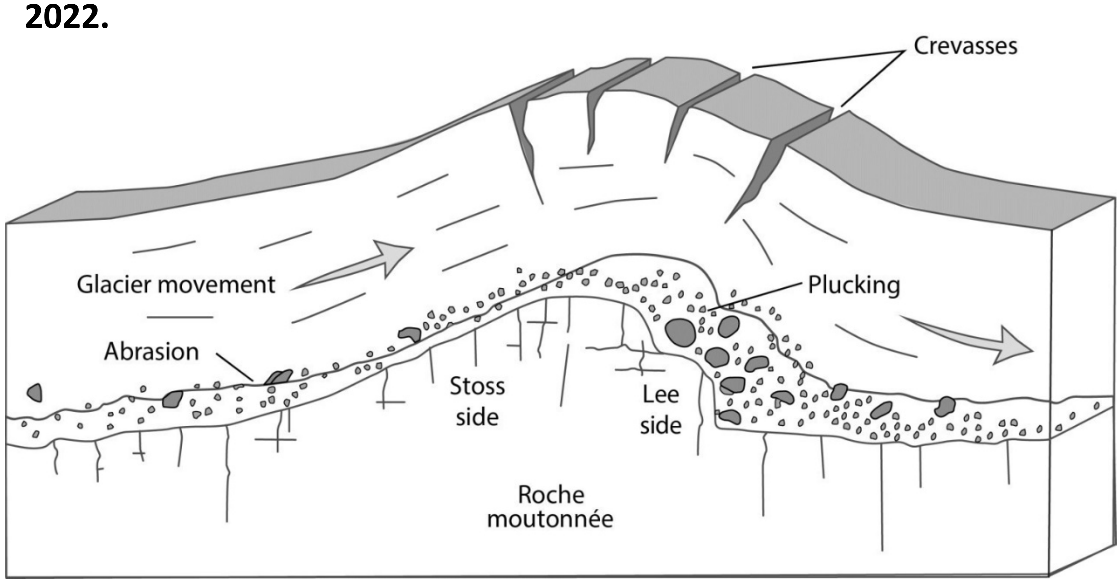

Figure 23. Diagram of the formation of asymmetrical roche moutonnee because of abrasion on stoss side and plucking on the lee side. Source: https://gq.mines.gouv.qc.ca/lexique-stratigraphique/quaternaire/roche-moutonnee_en/

Stop 5—Knob Hill

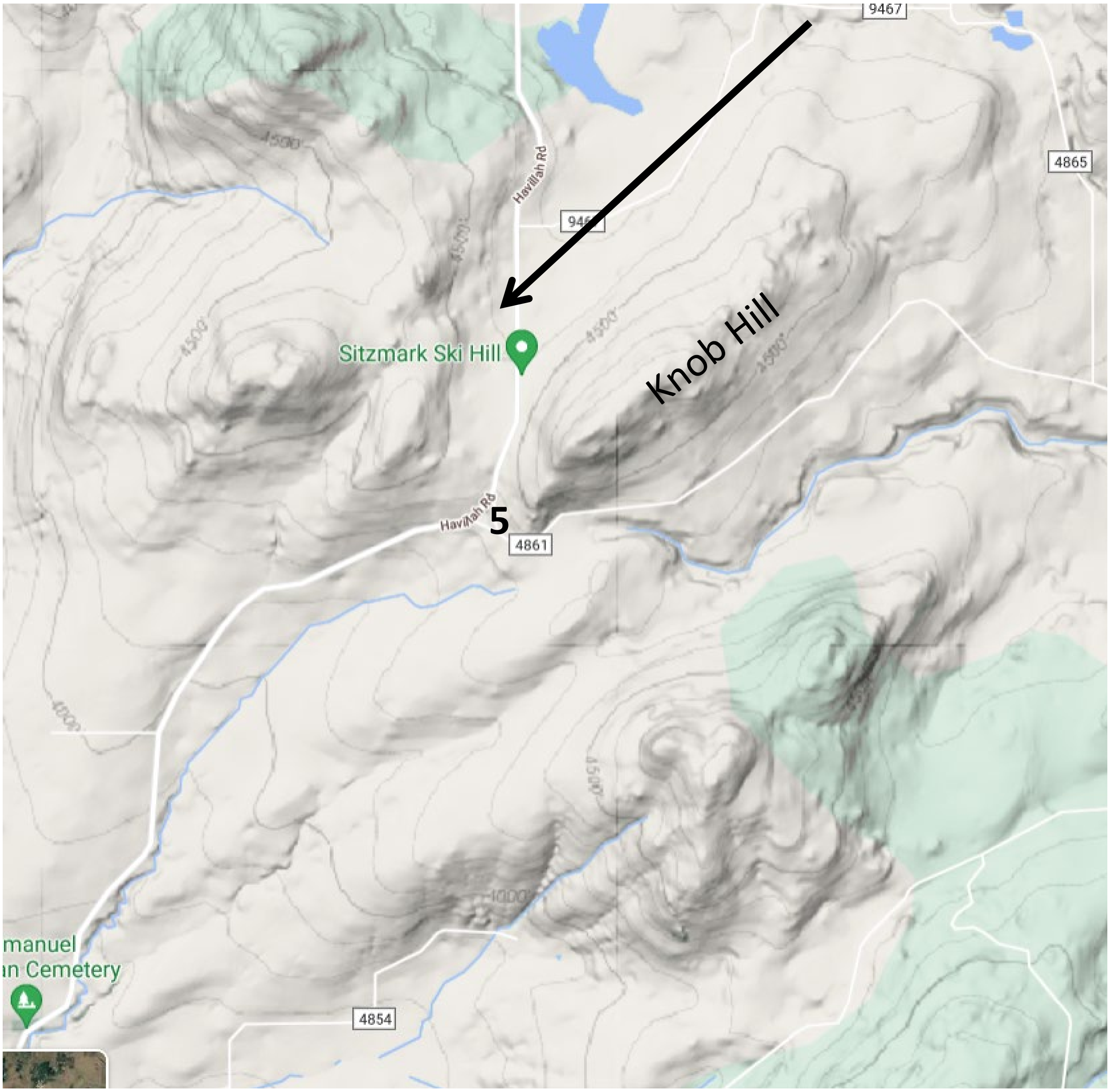

Figure 24. Map of Knob Hill area showing common orientation of hills. Note the steep south end of Knob Hill and the hills to the west. Arrow indicates likely ice movement direction that resulted in the common orientation of hills. Bold 5 indicates approximate location of Stop 5. From Google Maps.

Stop 5—Knob Hill

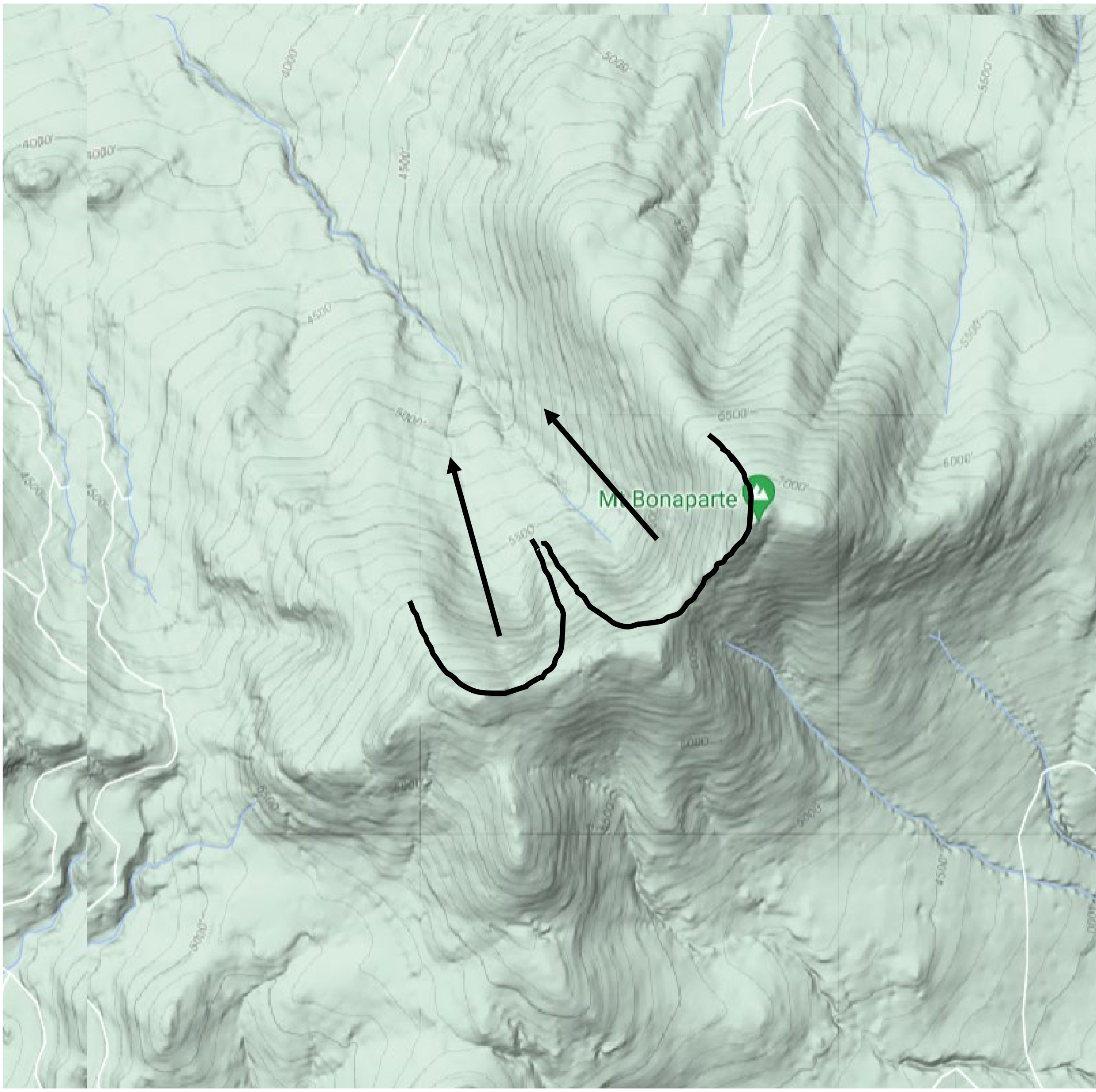

Figure 25. Map view of Mt. Bonaparte and its cirques. Arcuate cirques are highlighted with black lines. Ice flow direction indicated with arrows. Source: Google Maps.

Stop 5—Knob Hill

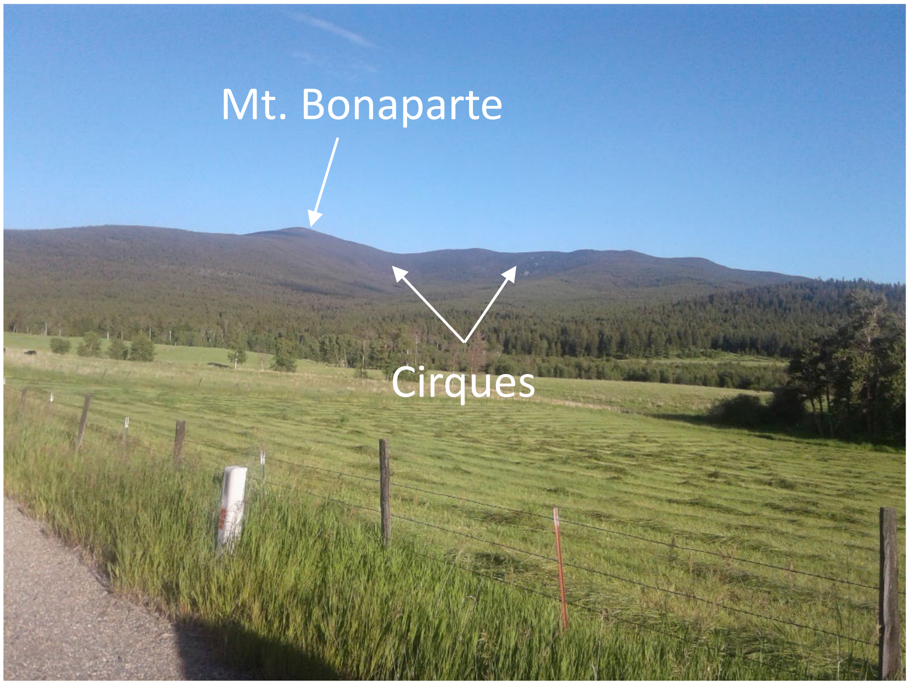

Figure 26. Mt. Bonaparte from Havillah-Lost Lake Road. Note cirques on the north side of the mountain. Author photo, June 2020.

Knob Hill to Antoine Creek Valley

From here to there…: From here continue a short distance to Nealey Road. Turn right on that road and proceed back to the Tonasket-Havillah Road. Turn left onto this road and follow it for about 12.25 miles to the Antoine Breaks Road. Turn right and find a place to park on the side of this road or in the gravel pit adjacent to the road. This is Stop 6. GPS coordinates are: 48.754018°N and 119.334851°W.

Glacial till and agriculture: The Havillah area has more non-valley bottom agriculture than either the Molson or Chesaw areas. Perhaps this is because of the generally south-facing slopes of the area that warm up earlier in the spring. Conversely, it may be associated with deeper soils formed in thicker glacier deposits. The numerous rock piles in the farm fields tell us that the soils here are rocky. Because rocks damage farm equipment it behooves the farmers to remove them from the fields and deposit them into rock piles. Perhaps archeologists of the future will be perplexed by these piles.

Knob Hill to Antoine Creek Valley

Havillah: Havillah was settled by German families in about 1910 (Writers Project, 1941). Presumably they came to the area on the Oroville to Spokane spur line of the Great Northern Railroad to farm. These families built the prominent Immanuel Lutheran Church in 1917 (Kirk and Alexander, 1990) and it remains in use to this day.

Stop 6—Antoine Creek Valley

Location. Our view here is of Antoine Creek Valley (**Figure 27**). This land is owned by the Western River Conservancy. Please treat it with respect.

Channel incision and bedrock gorges. *Gorges* are narrow, deeply incised, V-shaped channels formed in bedrock. The deep incision implies high stream flows, perhaps over a lengthy period of time. Antoine Creek is one of three gorges formed on the margins of the northern portion of the Okanogan Highlands (**Figures 27 & 28**). The others are North Fork Beaver Creek and Box Canyon, both of which are south of Chesaw. The Antoine Creek gorge, is nearly 500 feet deep in places but only about 1,400 feet across. A large alluvial fan or perhaps fan delta is present at the mouth of the gorge at the head of Antoine Valley. The surface of the fan is littered with large boulders suggesting high stream flows at times in the past. I suspect that each of these three gorges are related to the erosive effects of glacial meltwater. The Antoine Creek gorge would have received flow from the cirques on Mt. Bonaparte (Antoine Creek and Mill Creek), from the unnamed creek in the vicinity of Knob Hill, and from the creek in Eden Valley. It is also possible that Baker Creek, when it flowed south from the Molson area into the Tonasket Creek drainage continued south into the Eden Valley drainage and into Antoine Creek. This may appear to be a stretch of my imagination as the flow would have to ascend approximately 360 feet to get into the Eden Valley drainage. However, this might be accomplished with very high discharge (a glacial outburst flood?) or the absence of some or all of that relief at the pass separating Tonasket Creek from Eden Valley (from isostatic effects or a lack of glacial deposits at the pass?). And what is striking is that the drainage from the Molson area lines up well with the headwaters of Antoine Creek. A glacial outburst flood could also better help explain the origin of the Antoine Creek gorge. If a glacial outburst flood was responsible for the Antoine Creek gorge, related features such as large bars have yet to be identified.

Stop 6—Antoine Creek Valley

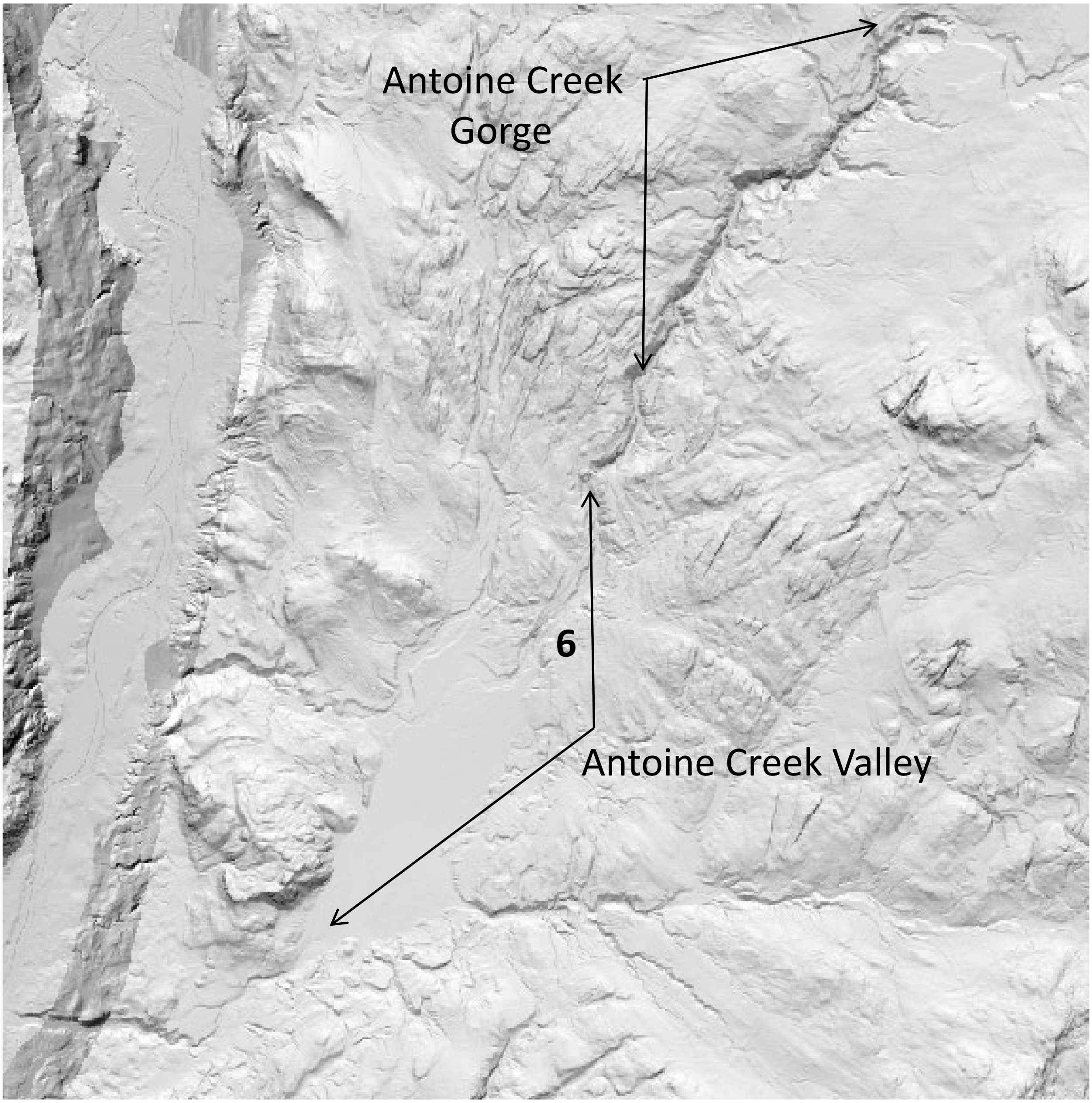

Figure 27. LIDAR view of Antoine Creek gorge and valley. Bold 6 indicates approximate location of Stop 6. Source: Washington LIDAR Portal.

Stop 6—Antoine Creek Valley

Glacial Lake Antoine? and another drainage diversion. The broad, flat floor of Antoine Valley (**Figure 27**) suggests that the valley was once occupied by a large (~2+ mile long) lake. Soils data supports this with the presence of fine textured soils on the basin floor, especially to the south (see Web Soil Survey). Also, logs from several water wells in the valley show as much as 20 ft of clay underlain by sand and gravel. I suspect that the lake was temporary, forming with floodwaters that were too great to exit the bottleneck at the south end of the basin via what is now Siwash Creek. At some point, lake? water in the valley overtopped a divide on the west side of the basin, resulting in the formation of a short, steep channel that delivered water and sediment to the Okanogan River south of Ellisford (**Figures 27 & 29**) .   Since that time, Antoine Creek has exited the basin to the west. A large alluvial fan at the Antoine Creek mouth attests to the amount of sediment transported to the Okanogan Valley. This fan is sufficiently large to have pushed the Okanogan River to the west.

From here to there…From here, continue south on the Tonasket-Havillah Road about 6.5 miles to US 97 in Tonasket. There, head south for about 0.5 mile to the intersection of US 97 and WA 20. Turn left (east) onto US 20 and return to our starting point at Tonasket High School.

Figure 28. View north to the mouth of Antoine Creek Gorge. Author photo, May 2022.

Stop 6—Antoine Creek Valley

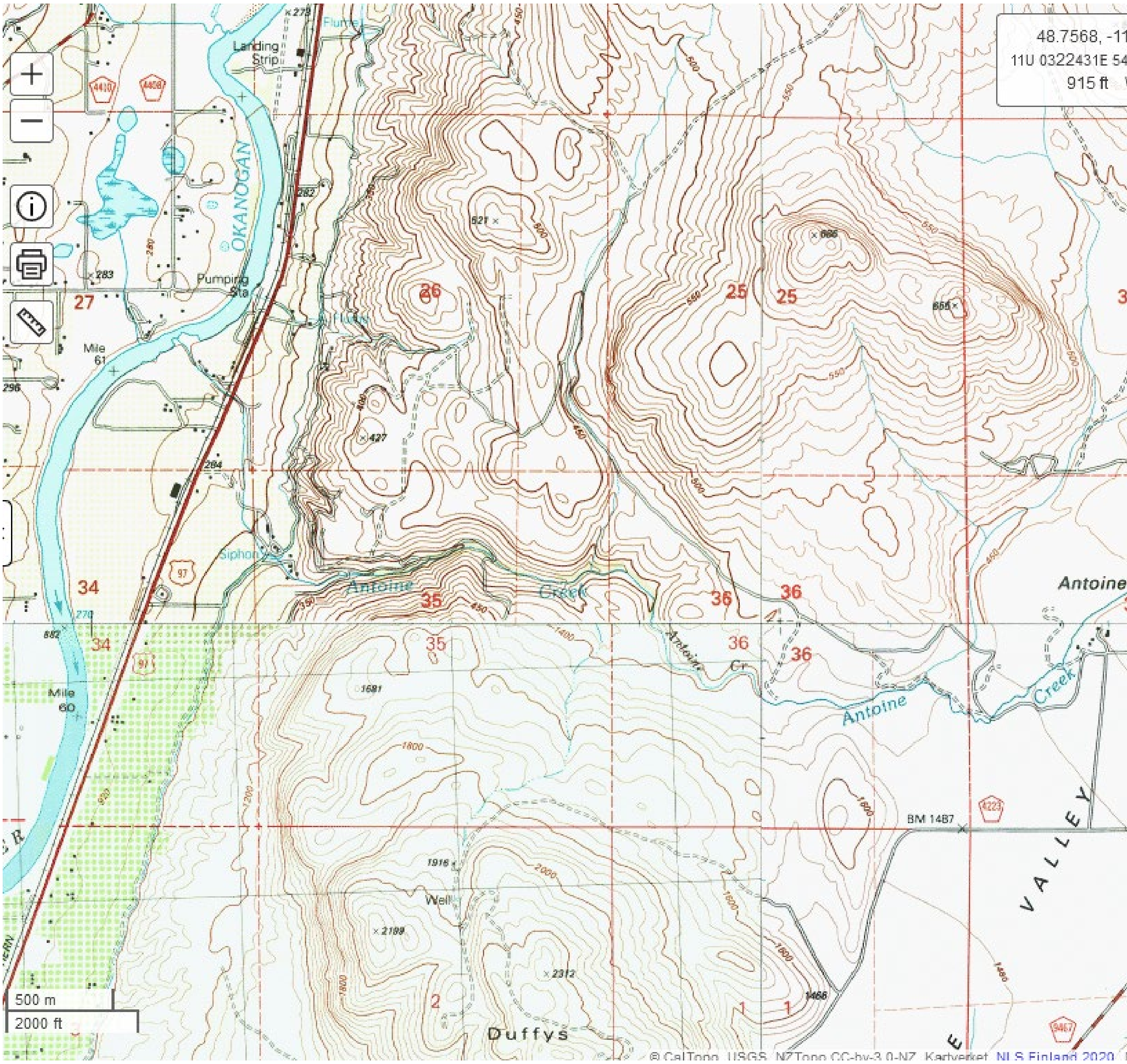

Figure 29. Topographic map view of current outlet of Antoine Creek. Not the large alluvial fan at the mouth of the creek that has pushed the Okanogan River to the west. From Caltopo.com.

Wrap-up

This trip was designed to explore a variety of landforms that show the different impacts of Pleistocene glaciation on the Okanogan Highlands. Along the way, we have also seen the impacts of bedrock, rivers, beavers, and humans in shaping the landscape. Feel free to contact me at lillquis@cwu.edu or 509 963-1184 if you have comments or questions about the landforms and landscapes of the Okanogan Highlands. Please support the Okanogan Highlands Alliance in their efforts to serve as environmental watchdogs, educators, and stewards.

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