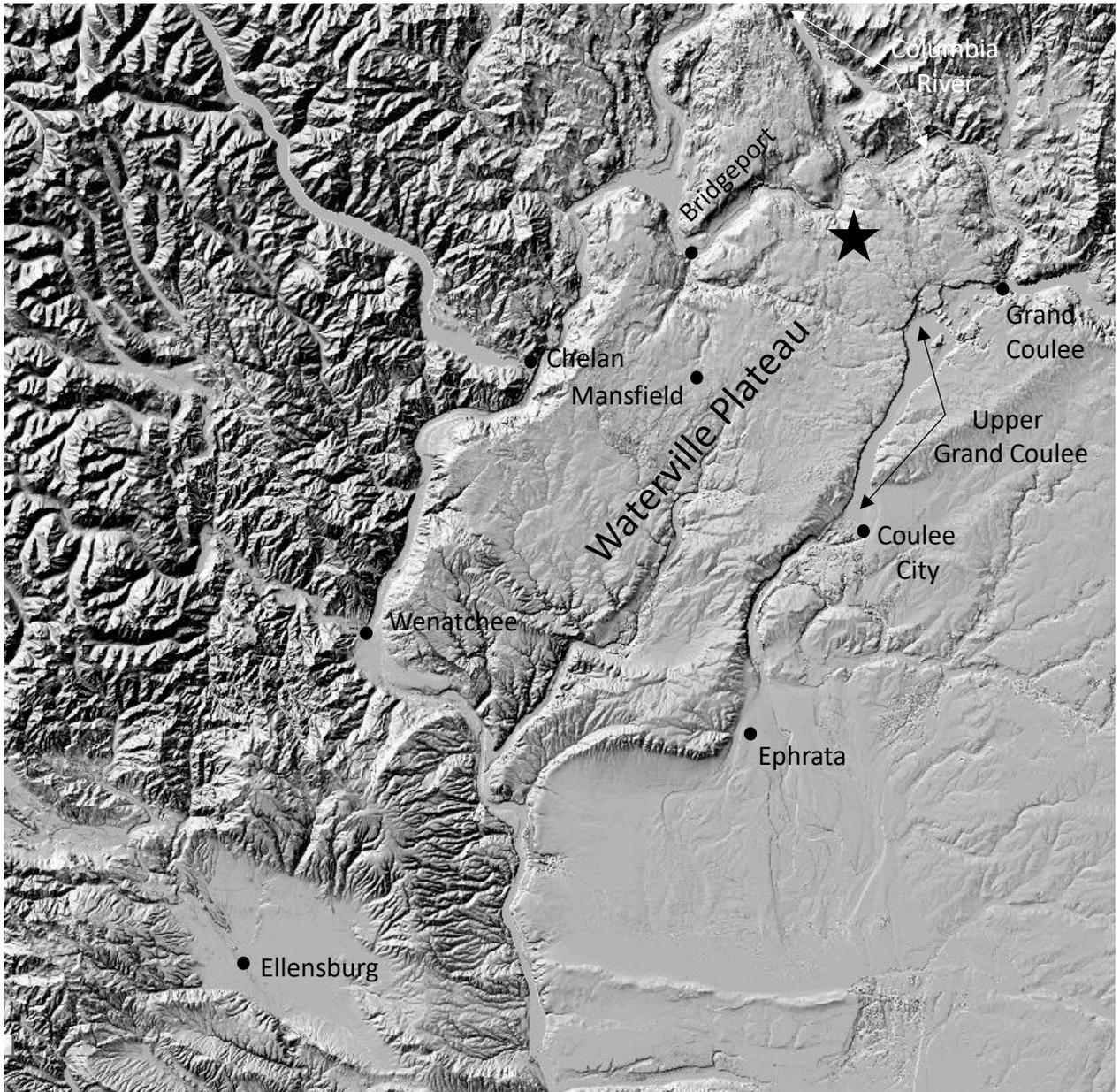


# Central Washington's Outback: Northeastern Waterville Plateau Field Trip



Field Trip Leader:  
**Dr. Karl Lillquist, Emeritus Professor**  
**Geography Department, Central Washington University**

14 June 2025

# Field Trip Overview

Welcome to the northeastern Waterville Plateau! This trip will encompass the little studied area from Crown Point and WA 174 northwest and north to the Columbia River. The focus of the day will be the Cordilleran Icesheet and its impacts on the physical and human landscape. Six field trip stops in this area (**Figure 1**) include: 1) Crown Point; 2) Northeast of Leahy Junction; 3) Trefry Canyon headwaters; 4) East of Osborne Corner; 5) Strahl Canyon; and 6) Columbia River Overlook. This Ellensburg Chapter of the Ice Age Floods Institute field trip is a companion trip to previous Waterville Plateau field trips—i.e., Across the Waterville Plateau, Glacial Lake Foster, and East of Moses Coulee (see my webpage--  
[https://www.cwu.edu/academics/geography/\\_documents/karl-lillquist.php](https://www.cwu.edu/academics/geography/_documents/karl-lillquist.php)).

## Tentative Schedule

10:00am **Stop 1—Crown Point**

10:45 Depart

11:15 **Stop 2—Northeast of Leahy Junction**

12:00 Depart

12:30 **Stop 3—Trefry Canyon Headwaters**

1:15 Depart

1:30 **Stop 4—East of Osborne Corner**

2:15 Depart

2:45 **Stop 5—Strahl Canyon**

3:30 Depart

3:45 **Stop 6—Columbia River Overlook**

4:30 Depart

## Getting to Stop 1

*Stop 1 is located on the eastern edge of the northeastern Waterville Plateau (see title page) about 2 miles north of Grand Coulee just off WA 174. At about the 2 mile point, turn off WA 174 onto on Crown Vista Point Road and follow this road about 1.3 miles to Crown Point Vista which is part of Steamboat Rock State Park. Park in the large parking lot here. One pit toilet is available. You will need a Discover Pass to park here. GPS coordinates here are: 47.971525°N and 118.986765°W.*

# Stop 1—Crown Point Vista



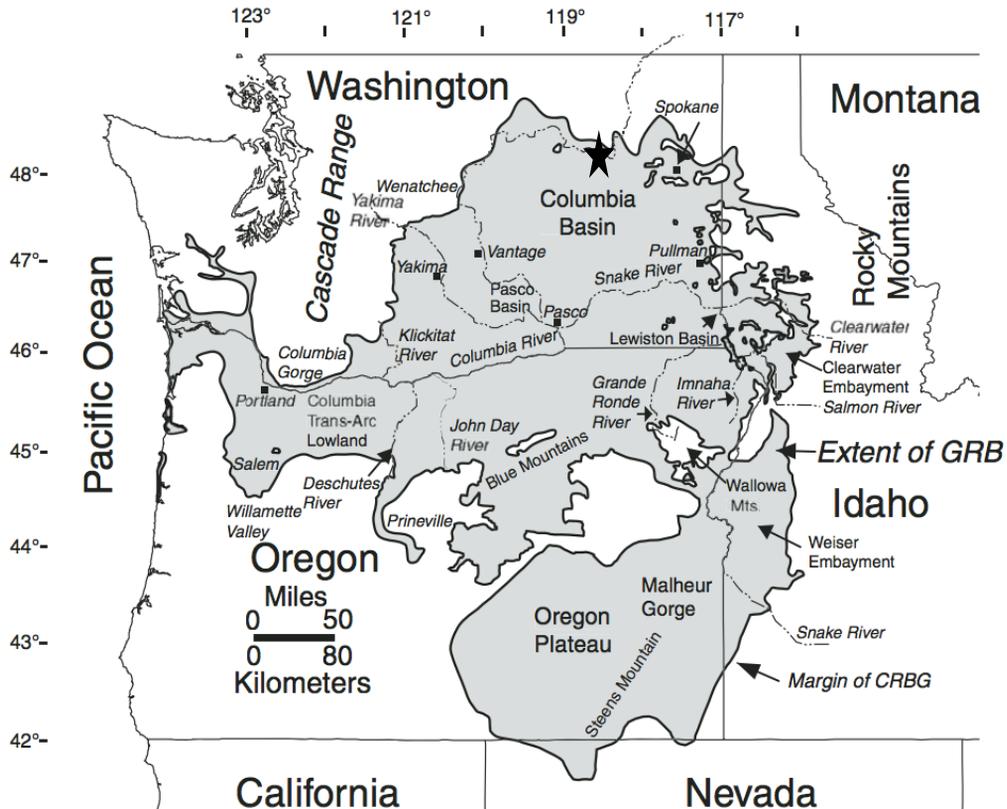
**Figure 1. The approximate locations of northeastern Waterville Plateau field trip stops noted with white circles. North is toward top of image. Source: Google Earth Pro, 12/30/2010.**

**Location:** Crown Point Vista sits above the Columbia River and has a great view of the Columbia River Valley and Grand Coulee Dam (Figure 2). We will talk near the kiosk overlooking the river.



**Figure 2. Stop 1 in relation to Grand Coulee and WA 174. Bold number indicates location of Stop 1. North is toward top of map. Source: Google Maps.**

# Stop 1—Crown Point Vista



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

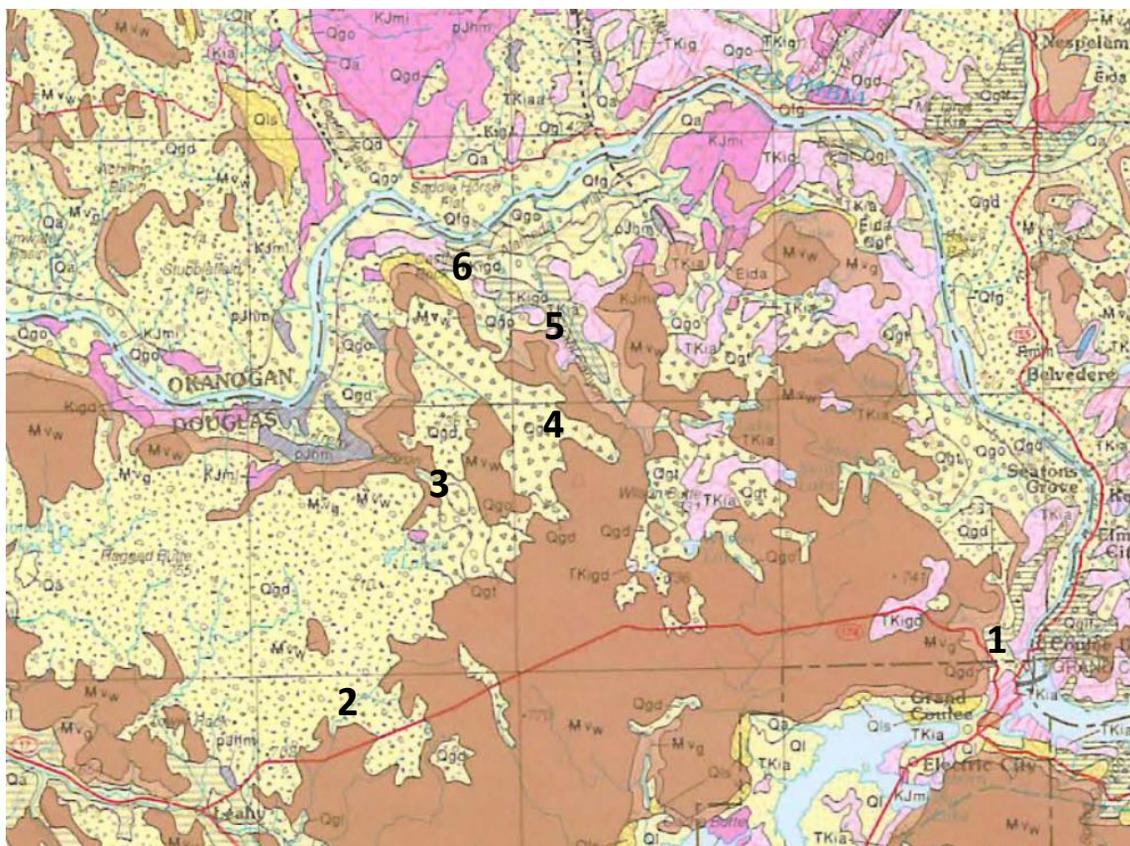
**Bedrock Geology.** The bedrock geology of our field day is Miocene Columbia River Basalt and Late Cretaceous/Early Tertiary granites and granodiorites (Stoffel & others, 1991). Dark, dense, volcanic basalts characterize much of central and eastern Washington (Figure 3). The specific basalts of our field day are the 16.5—14.5 million year old (ma) Grande Ronde and Wanapum Basalts (including the Priest Rapids and Roza members) (Gulick and Korosec, 1990a, 1990b). Each member is a different basalt flow, and as you can see by Figure 4, there are many flows composing the entire Columbia River Basalt Group. The granites & granodiorites range from Mesozoic to early Tertiary in age (Stoffel & others, 1991). The position of the field area in two general types of bedrock (Figure 5) means we are in a geological transitional zone—a “geotone”—that leads to interesting soils and associated vegetation patterns.

# Stop 1—Crown Point Vista

Series	Group	Formation	Member	Isotopic Age (m. y.)	Magnetic Polarity	
Miocene	Upper	Saddle Mountains Basalt	Lower Monumental Member	6	N	
			Ice Harbor Member	8.5		
			Basalt of Goose Island		N	
			Basalt of Martindale		R	
			Basalt of Basin City		N	
			Buford Member		R	
			Elephant Mountain Member	10.5	R <sub>1</sub>	
			Pomona Member	12	R	
			Esquatzel Member		N	
			Weissnefels Ridge Member			
			Basalt of Slippery Rock		N	
			Basalt of Tenmile Creek		N	
			Basalt of Lewiston Orchards		N	
			Basalt of Cloverland		N	
			Asotin Member	13		
	Basalt of Huntzinger		N			
	Wilber Creek Member					
	Basalt of Lapwai		N			
	Basalt of Wahluke		N			
	Umatilla Member	13.5				
	Basalt of Sillusi		N			
	Basalt of Umatilla Member		N			
	Middle	Columbia River Basalt Group	Wanapum Basalt	Priest Rapids Member	14.5	
				Basalt of Lolo		R
				Basalt of Rosalia		R
				Roza Member		T.R
				Shumaker Creek Member		N
				Frenchman Springs Member		
				Basalt of Lyons Ferry		N
				Basalt of Sentinel Gap		N
				Basalt of Sand Hollow	15.3	N
				Basalt of Silver Falls		N.E
				Basalt of Ginkgo		E
Basalt of Palouse Falls					E	
Eckler Mountain Member						
Basalt of Dodge					N	
Basalt of Robinette Mountain					N	
Vantage Horizon						
Lower	Columbia River Basalt Group	Grande Ronde Basalt	Member of Sentinel Bluffs	15.6	N <sub>2</sub>	
			Member of Slack Canyon			
			Member of Field Springs			
			Member of Winter Water			
			Member of Umtanum			
			Member of Ortley			
			Member of Armstrong Canyon			
			Member of Meyer Ridge			
			Member of Grouse Creek			
			Member of Wapshilla Ridge			
			Member of Mt. Horrible			
			Member of China Creek			
			Member of Downey Gulch			
Member of Center Creek						
Member of Rogersburg						
Member of Teepee Butte						
Member of Buckhorn Springs	16.5					
Picture Gorge Basalt	Columbia River Basalt Group	Imnaha Basalt			R <sub>1</sub>	
					T	
					N <sub>n</sub>	
					R <sub>n</sub>	
			17.5			

**Figure 4. Stratigraphy of the Columbia River Basalt Group. Recent research indicates that the Vantage horizon formed at 16.1-16.0 mya, and that an ash bed in the Priest Rapids Member formed at about 15.9 mya. Source: <https://www.usgs.gov/centers/oregon-water-science-center/science/columbia-river-basalt-stratigraphy-pacific-northwest#multimedia>; Andy Miner, written communication, November 3, 2021.**

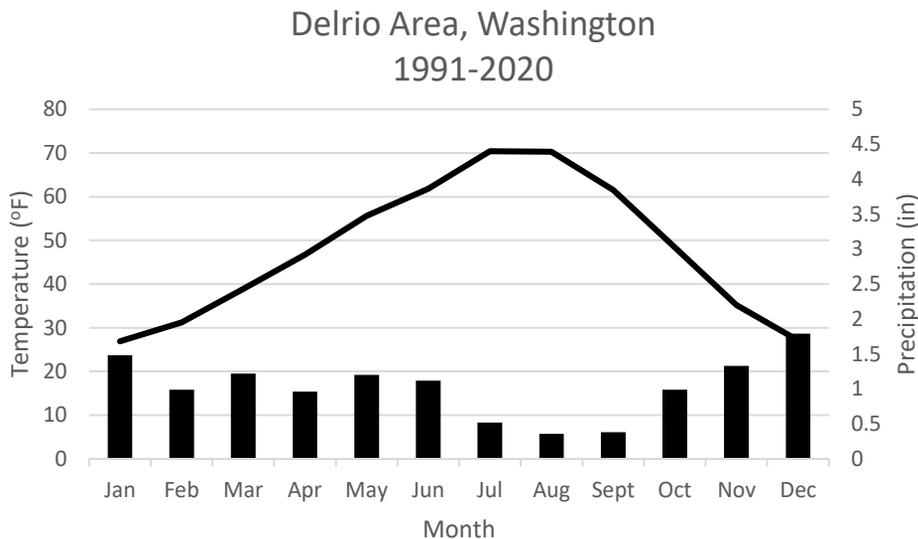
# Stop 1—South of Leahy Jct.



**Figure 5. Geology of the northeastern Waterville Plateau and surroundings. bright pink = Cretaceous & Jurassic metamorphic & igneous rocks; light pink = Cretaceous & Tertiary granites & granodiorites; brown = Miocene Columbia River Basalts; and light yellows = Quaternary glacial drift, glacial lake sediments & loess. Bold numbers indicate approximate locations of field trip stops. North is toward top of map. Source: Stoffel & others (1991).**

**Weather & Climate.** The climate of the area may be characterized as a mid-latitude dryland (Figure 6). The mid-latitude and inland location means that summers are hot and winters are cold. The average annual temperature is about 48°F, a value lower than marine-influenced Seattle and slightly less than more continental Spokane. The location in the rain shadow of the Cascade Range results in overall drier conditions (~12 inches of precipitation/year) than Seattle and Spokane. Most precipitation occurs in the cooler months (October-March) and is associated with the passage of mid-latitude cyclones (i.e., low pressure “storms”). Wind is common throughout the year with the most common and strongest coming from the west. Given the dry and windy setting, potential evapotranspiration is likely more than three times the precipitation (Donaldson and Ruscha, 1975)!

# Stop 1—Crown Point Vista

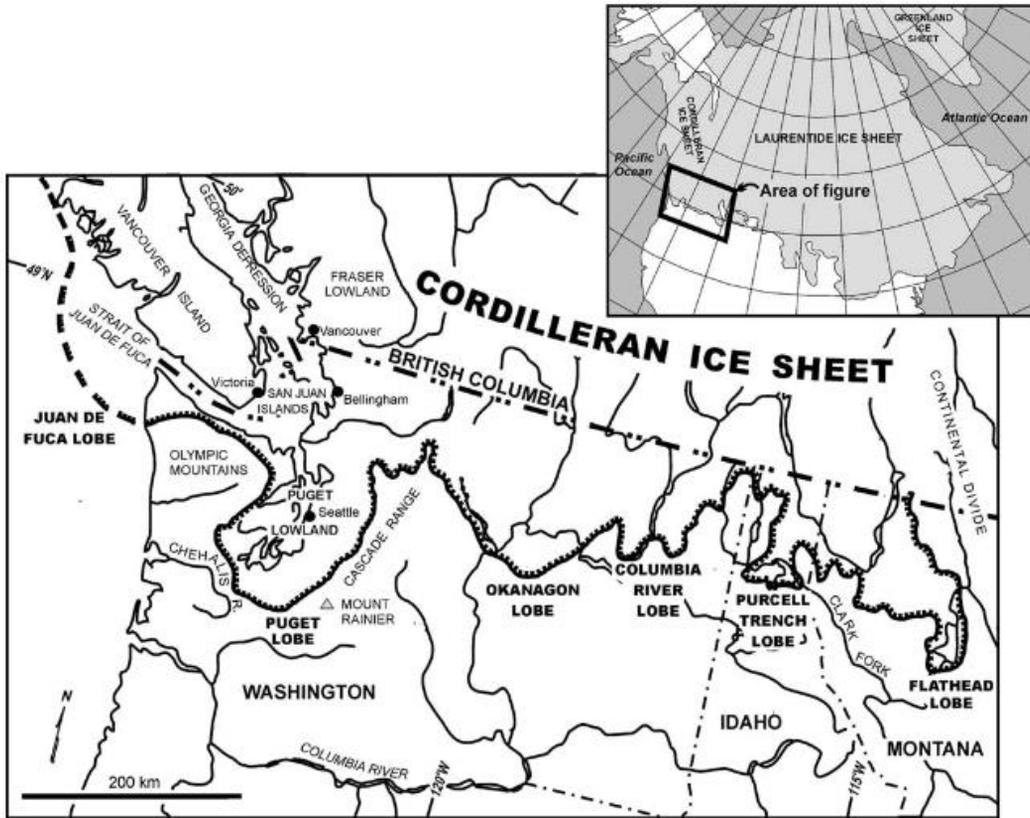


**Figure 6. Modeled temperature (line graph) and precipitation (bars) for the Delrio area on the northeastern Waterville Plateau over the 1991-2020 climate normal. Note the sharp contrast between winter and summer temperatures, and the marked low summer precipitation. From PRISM Climate Group website (<https://prism.oregonstate.edu/explorer/>).**

**Biota.** Given the 12” average annual precipitation, we are located on the margins of shrub steppe and east side forest. Therefore, we see shrub steppe on the drier sites (especially south-facing slopes) while ponderosa pine and Douglas fir grow on the cooler and moister north-facing slopes. Such marginal or transitional zones—i.e., “ecotones”—were productive places for hunter gatherers because of the variety of environments in close proximity.

**Cordilleran Ice Sheet.** While the Waterville Plateau can be cold and snowy in the winter months, and was colder and perhaps snowier in the Late Pleistocene Ice Age, it was not sufficiently so to create glaciers here. The Cordilleran ice Sheet that shaped much of northwestern North America formed in the colder and snowier Coast Mountains and Rocky Mountains of British Columbia (Clague and James, 2002) (Figure 7). As it grew, it moved away from its mountain sources as five distinct lobes—Puget (to the west), the Okanogan (here), and the Columbia River, Purcell Trench, and Flathead to the east (Figure 7).

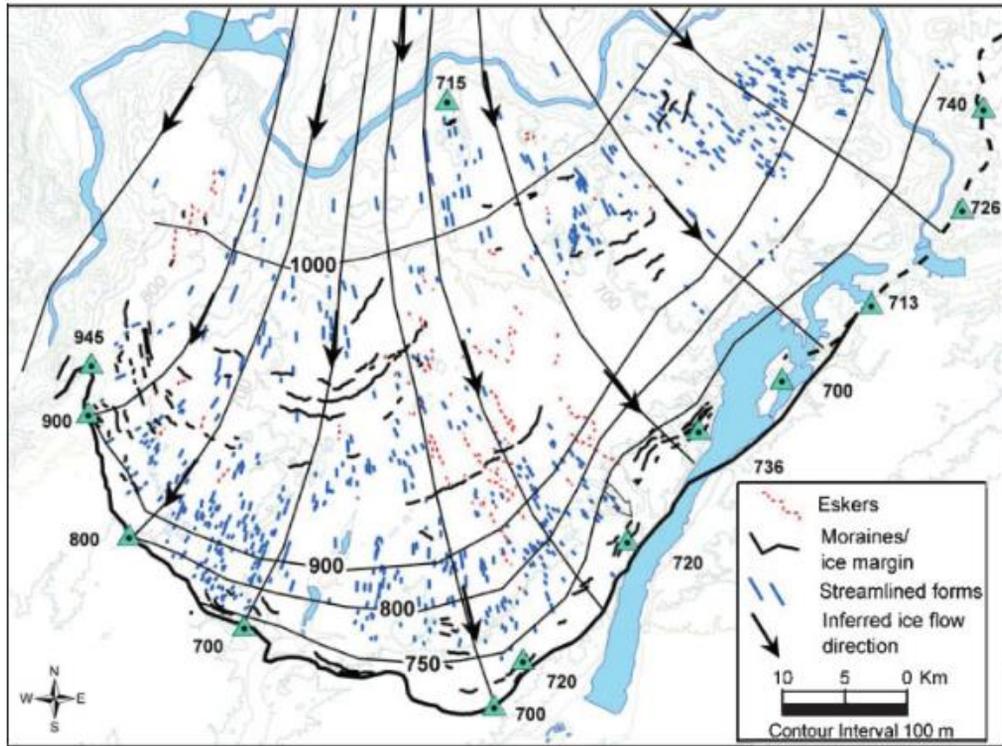
# Stop 1—Crown Point Vista



**Figure 7. The five lobes of the Cordilleran Icesheet in northwestern North America. Source: Booth & others (2003).**

**Okanogan Lobe.** Because the Okanogan Lobe flowed away from the main mass of the Cordilleran Ice Sheet, we refer to it as an “outlet glacier” (Kovanen and Slaymaker, 2004). As the largest of the four lobes east of the Cascade Crest, it blocked and re-routed the Columbia River and huge Ice Age floods (e.g., Missoula Floods). As we will also see on this field trip, it left a diverse array of landform evidence. During the late Pleistocene glaciation, the Okanogan Lobe advanced onto the Waterville Plateau between 19-17 ka (i.e., thousand years) (Gombiner, 2022). It terminated about 20 miles south of here between 17-15 ka (Gombiner, 2022). The ridge-like end moraine that marks that terminus—Withrow Moraine-- is named for the village of Withrow southwest of here (Bretz, 1923). The ice was at least 700 ft thick at the Withrow Moraine and increased to over 1600 ft thick on the north end of the plateau (Figure 8) (Kovanen and Slaymaker, 2004). Retreat from the Waterville Plateau occurred between 15-13 ka (Gombiner, 2022). While evidence exists elsewhere for pre-late Pleistocene glaciations, nothing definitive has been found on the Waterville Plateau (Gombiner & Lesemann, 2024).

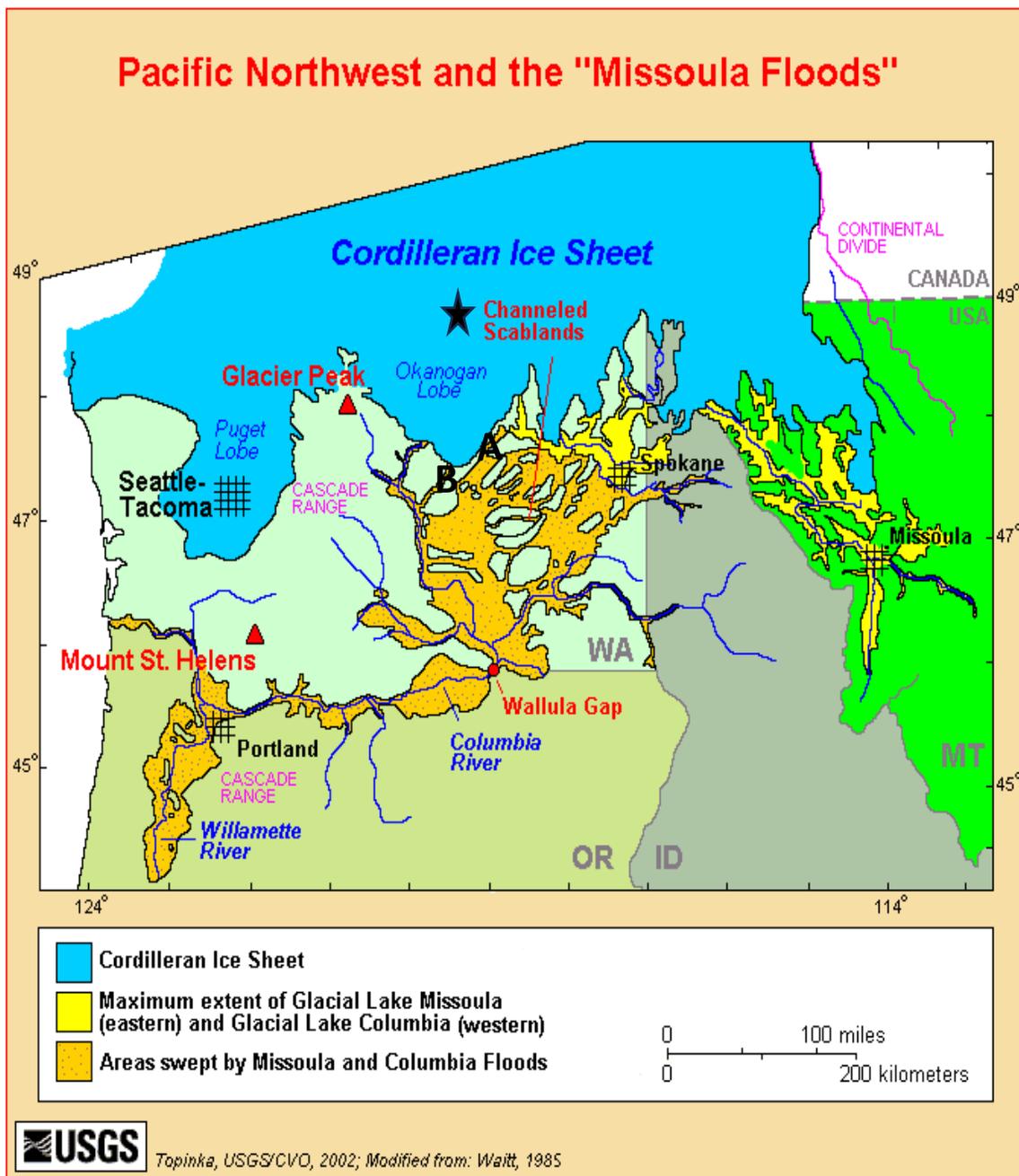
# Stop 1—Crown Point Vista



**Figure 8. Ice flow system and ice surface elevations of the Okanogan Lobe on the Waterville Plateau. Source: Kovanen and Slaymaker (2004).**

**Glacial Lake Missoula Floods:** Most of the floods that shaped Eastern Washington came from Glacial Lake Missoula in western Montana ([Figure 9](#)). Glacial Lake Missoula originated when the Purcell Trench Lobe of the Cordilleran Icesheet blocked the mouth of the Clark Fork River near present-day Lake Pend Oreille and Sandpoint creating Glacial Lake Missoula. At its maximum, it held 530 mi<sup>3</sup> of water which is about one-half the volume of modern-day Lake Michigan. It was 2,000 feet deep at its ice dam! Periodically, the ice dam failed releasing lake waters as glacial outburst floods (or “jokulhlaups”) that swept across northern Idaho and into northeastern Washington. Floodwater velocities reached nearly 70 mph in places! Much of the path of these floods was scoured to basalt bedrock and descriptively named the “Channeled Scablands” ([Figure 9](#)). We are located about 12 miles west of a prominent feature of the Channeled Scablands—the Grand Coulee. See Bretz (1969), Baker & others (2016), and Waitt & others (2021) for excellent summaries of the Ice Age flood history here.

# Stop 1—Crown Point Vista



**Figure 9. Late Pleistocene Cordilleran Icesheet and Missoula Floods in the Pacific Northwest. Star indicates approximate location of the field trip. A is upper Grand Coulee and B is Moses Coulee. North is toward top of map. Source: Cascade Volcano Observatory website, <https://www.usgs.gov/media/images/pacific-northwest-and-missoula-floods>.**

# Stop 1—Crown Point Vista

**Okanogan Lobe & the Upper Grand Coulee.** The Upper Grand Coulee formed when the Okanogan Lobe of the Cordilleran Icesheet blocked the Columbia River Valley near the present-day towns of Grand Coulee and Coulee Dam thus creating Glacial Lake Columbia (Figure 9). This lake spilled to the south as did Ice Age floods entering the lake. Floods down the Upper Grand Coulee could follow multiple paths to arrive in the Quincy Basin because of the shear volume of water exiting the Upper Grand Coulee and the lack of the topographic confinement there. Dry Falls and the Lower Grand Coulee is the most prominent of these paths. Numerous (perhaps as many as 90 floods) of varying magnitudes passed through the Upper Grand Coulee during the late Pleistocene. More may have come through during earlier glacial periods (Waitt & others, 2021)

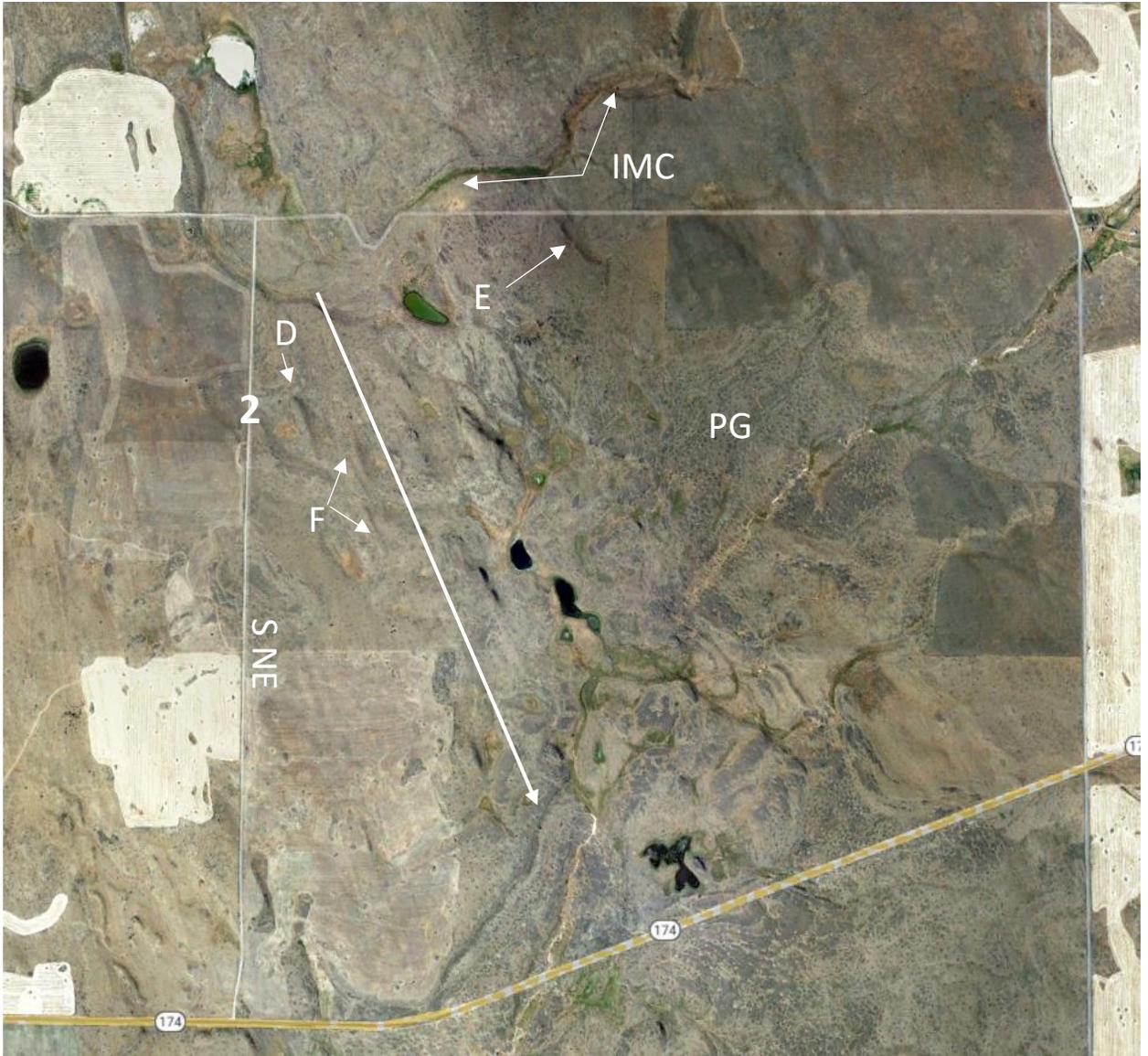
**Okanogan floods:** It is more difficult to attribute the origin of Moses Coulee (Figure 9) to floods from Glacial Lake Missoula. Bretz (1923) recognized this first citing a lack of channel connectivity to the channeled scablands. Freeman (1933) first suggested the Okanogan Lobe as a source for these floodwaters. More recently, Gombiner and Lesemann (2024) used the presence and orientation of “anastomosed tunnel valleys” that formed beneath the Okanogan Lobe as evidence of catastrophic subglacial floodwaters to explain the origin of Moses Coulee. We will visit tunnel valleys at Stop 3.

## Enroute to Stop 2

**Route:** *Return to WA 174 and head uphill toward Leahy Junction and Bridgeport. You are travelling through a very sparsely populated portion of Washington. This sparseness is linked to the scouring impacts of ice age floods and glaciers, the dry climate, and the agricultural economy. These three points have resulted in a setting that is most conducive to ranching which requires large tracts of land. It is about 17 miles from the junction of Crown Vista Point Road and WA 174 to road S NE. Turn right onto this good gravel road and proceed north about 1.5 miles to Stop 2 (Figure 10). Make sure to park along the side of the road so other vehicles may pass. The GPS coordinates of this stop are: 47.954654°N & 119.341439°W.*

# Enroute to Stop 2

**Location.** From our parking spot along road S NE, we will cross the fence on the east side of S Rd NE and enter a parcel of Washington state land.



**Figure 10. Broad view of Stop 2 including drumlins (D), flutes (F), eskers (E), ice marginal channel (IMC), and patterned ground (PG). Arrow indicates general ice flow direction here. Bold number indicates approximate location of Stop 2. North is toward top of map. Source: Google Earth Pro, 09/13/2011.**

# Stop 2—Northeast of Leahy Jct.

**Glacier movement.** Glacier advance is caused by glacial ice mass and underlying landscape slope. Glacial ice advances occur when glacial mass grows (e.g., from snow accumulation) in the glacier accumulation area (i.e., British Columbia) to exceed outputs (e.g., glacier melt) (i.e., near here). Glaciers move by internal deformation (i.e., “flow”) of the ice and by sliding on their bases (i.e., “basal sliding”). Basal sliding may be enhanced by the presence of subglacial water. Because of its relatively low latitude and associated relatively warmer temperatures, the Okanogan Lobe was considered to be a wet- (or warm) based glacier therefore had ample meltwater (Kovanen & Slaymaker, 2004).

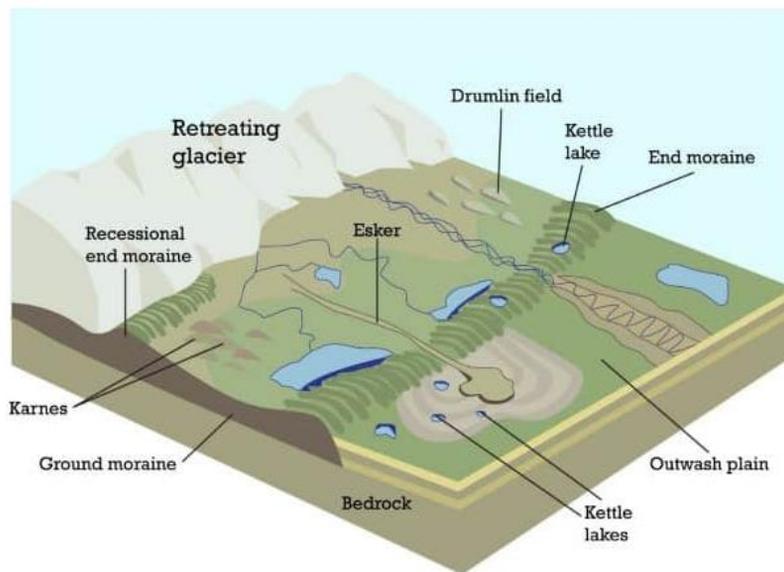
**Advancing ice indicators.** Advancing glaciers tend to erode landscapes in the direction they travel. This erosion results in a distinctive set of landforms that range in scale from inches or a few feet (e.g., striations), tens of feet (e.g., flutes) to hundreds of feet (e.g., drumlins) (Figure 11). All are linear features that form parallel to ice movement. Striations form when rock, embedded in the base of a glacier, gouges the underlying bedrock. This results in linear grooves that are typically less than an inch wide and ranges up to several feet long. Striations are widespread on basalt outcrops on the plateau (e.g., Russell, 1893) but I have yet to find evidence of them here.

Flutes are narrow, low ridges formed as overlying ice deforms saturated sediment into streamlined forms. This often occurs in the lee of an obstruction, like a bedrock knob (Benn and Evans, 1998). Note the flutes on Figure 10.

Drumlins are larger, rounded and streamlined hills with upglacier ends typically blunt and wider than the gently tapering downglacier ends (Figures 10-12). They have been described as looking like inverted spoons. Most often, they are composed of unconsolidated sediments—e.g., till and/or outwash. Sometimes, they are partially composed of bedrock. Drumlins may form from glacial erosion, deposition, or a combination of both (Benn & Evans, 1998). They may also form from erosion of basal ice then the subsequent filling of that “mold” with glacial till or glaciofluvial sediments (e.g., Shaw, 1983). This is a reminder of the basic geomorphic concept of “equifinality”—i.e., different processes may result in similar features.

Measurement of the orientation of the drumlin and adjacent flutes at Stop 2 indicates an ice flow direction here of about 160° (i.e., toward the south southeast). This matches up well with the work of others (e.g., Kovanen and Slaymaker, 2004) who show the radial nature of glacial flow on the Waterville Plateau (Figures 8 & 13).

# Stop 2—Northeast of Leahy Jct.

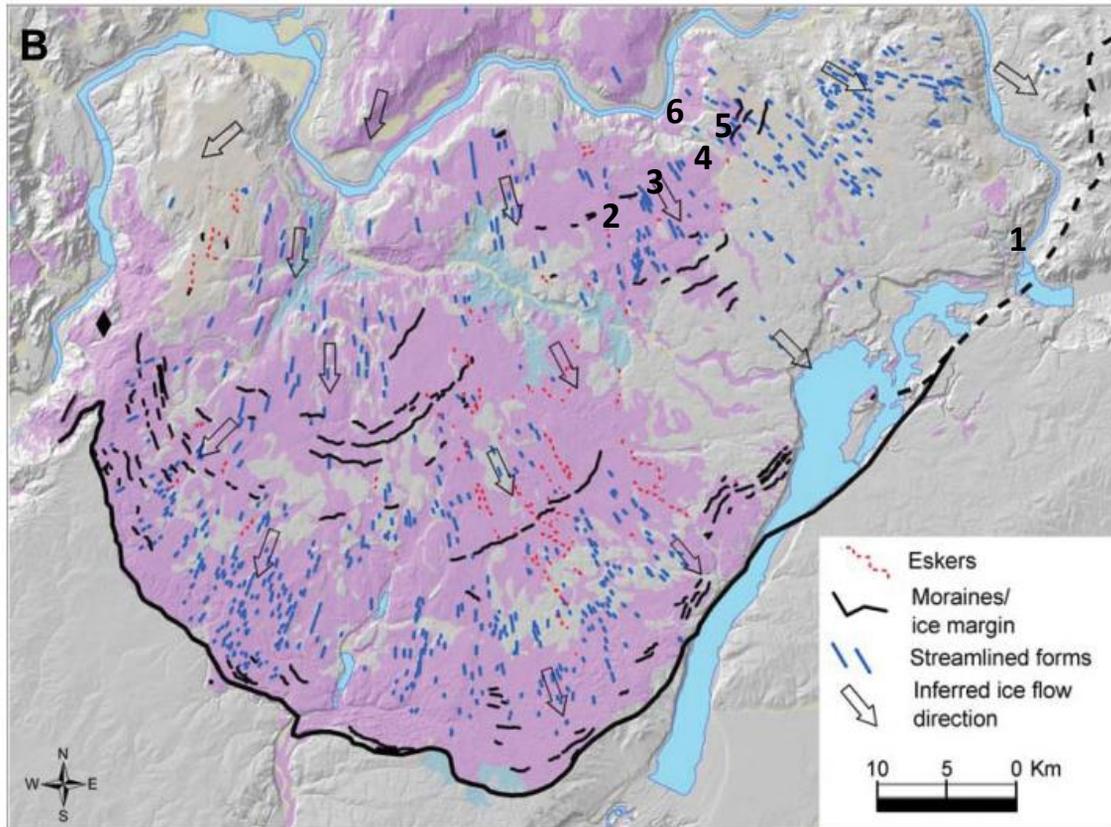


**Figure 11. Ice sheet and associated landforms exposed after glacial retreat. Source: <https://lotusarise.com/glacial-landforms-upsc/>**



**Figure 12. Side view of prominent drumlin at Stop 2. Ice movement direction indicated with bold arrow. View toward east. Source: Author photo, 04/11/2025.**

## Stop 2—Northeast of Leahy Jct.



**Figure 13. Streamlined forms (i.e., drumlins, flutes, and striations), eskers, and moraines on the Waterville Plateau. Streamlined forms indicate ice direction movement. Eskers commonly form parallel to streamlined forms and moraines form perpendicular to these features. Bold numbers indicate approximate field trip stop locations. Source: Kovanen and Slaymaker (2004).**

**Stream channels & ponds.** You may be surprised to see stream channels and depressions holding ponds in this dry environment. While the channels are mostly dry, the ponds typically hold water for part of the year from cool season precipitation. The channel and depressions are harder to explain, especially since they formed in basalt bedrock. We will explore these further at Stop 3.

**Soil Mounds and Patterned Ground.** Little soil is present on the basalts here except as scattered mounds. These mounds create a “pimpled” pattern on the landscape hence are one form of “patterned ground” (Figure 10). The patterned ground mounds are indicated by patches of big sagebrush. On these surfaces, the mounds are only 1-3 feet thick. How did the mounds form? Perhaps they are remnants of a once, nearly continuous surface of silty soil atop the basalts. Conversely, they may have formed as plants caught and

## Stop 2—Northeast of Leahy Jct.

**Soil Mounds and Patterned Ground (continued)**... accumulated windblown silts. Or are they a result of intense freezing and thawing (Washburn, 1988)? Whatever the origin, the silts came after the glacier receded and were likely associated with wind erosion of glacial outwash on the Waterville Plateau and/or wind erosion of Ice Age flood deposits in basins to the south.

## Enroute to Stop 3

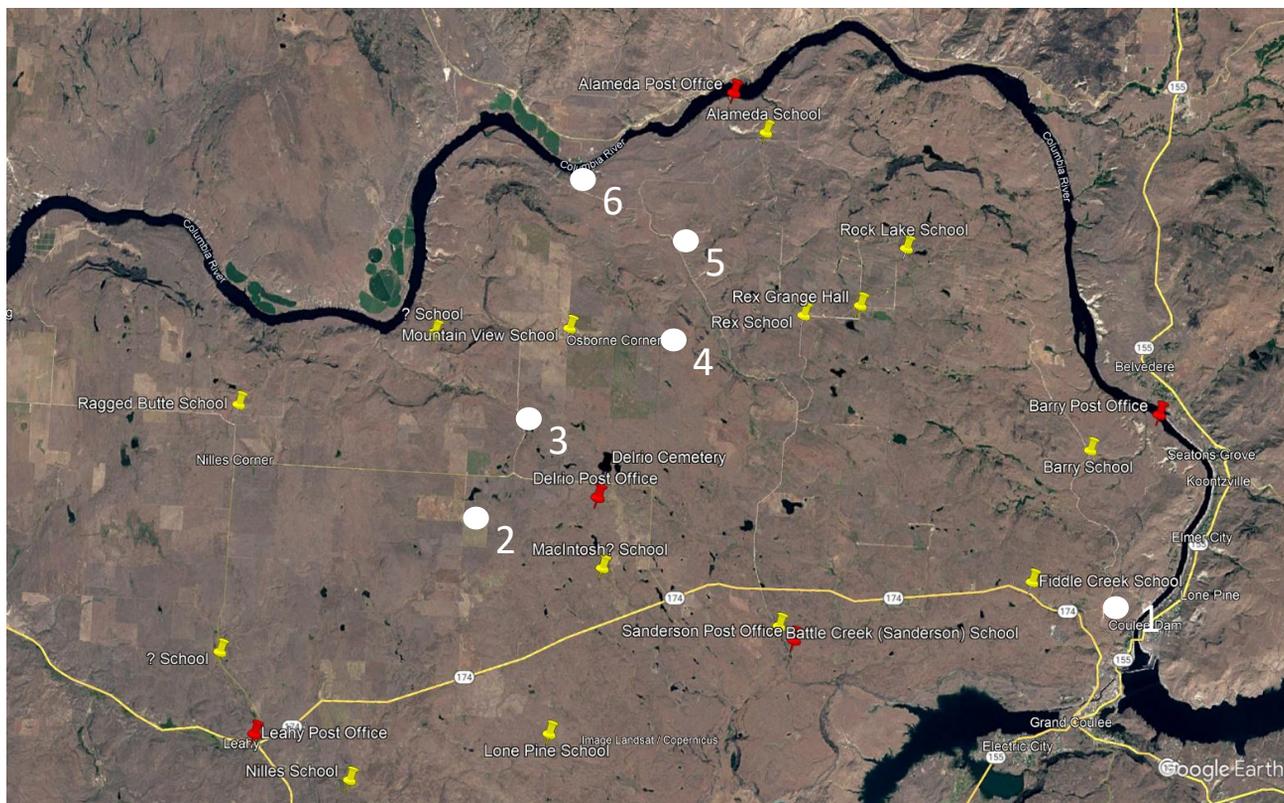
**Route.** *Continue north on gravel road S NE for ~0.5 mile, then turn left (west) onto gravel road 24 NE. Follow this road west for ~3.1 miles to paved road P NE (i.e., Leahy N). Several drumlins and flutes, and a complex of eskers are present along this road. Ragged Butte, a large basalt hill to the north, was either shaped or transported by the Okanogan Lobe.*

*At paved road P NE, turn right and drive 3 miles north to Nilles Corner.* Euroamericans began to settle this area by the 1880's with most homesteads filed between 1890 and 1910 (Rinker, 1976a). The local economy has long been agriculture-based with wheat farming and cattle ranching persisting through time (Rice, Rankin & Rankin, 1976). However, horse raising (Lee Hemmer, oral communication, April 2025) occurred early on, and several dairies and at least one orchard were once a large part of the ranching component (Ogle, 1915). With settlement came at least six small communities—Alameda, Barry, Delrio, Leahy, Rex, and Sanderson (Figure 14). Each had post offices, and Leahy and Delrio each had a store and a church. There was also a church near Sellers Landing on the Columbia River (Trefry, 1976). Fourteen schools were present in this part of Douglas County as of 1915 (Ogle, 1915; McGrath, 1989) (Figure 14). Over time, the communities and associated post offices, schools, and businesses faded away with the impacts of weather, agricultural markets, economies of scale, and government agricultural programs. Now, only scattered farms and ranches remain.

*At Nilles Corner, turn right onto paved (and later gravel) road 27 NE (i.e., Delrio Road) and drive east for ~6 miles to its junction with road V NE. Note the impacts of glaciation of land use which is now primarily dryland wheat farming and cattle ranching. Dryland agriculture involves farming a parcel of land one year, then leaving that same parcel “fallow” the following year to gather moisture. Over time, farmers removed rocks from glaciated fields or farmed around them creating rock piles and irregularly shaped fields. Much of the non-farmed areas are used to graze cattle.*

*At the junction with road V NE, turn left onto road V NE and drive north ~1 mile. Park on the side of the road taking care to leave sufficient room for vehicles to pass (Figure 14). GPS coordinates: 48.022339°N & 119.275625°W.*<sup>16</sup>

# Enroute to Stop 3



**Figure 14. Schools, post offices, and cemeteries of the Northeastern Waterville Plateau. Approximate locations of field stops shown in bold numbers. North is toward top of image. Sources: Google Earth Pro; Ogle, 1915; McGrath, 1989; Ruby & Brown, 1974; Seiler, 1976 (and various sources within).**

## Stop 3—Near Trefry Canyon

**Location.** We are located just above Trefry Canyon, tributary to the Columbia River. Walk east on Washington state land for about 0.1 mile to a distinctive landform in the bottom of the valley.

**Tunnel valleys.** We often think of the work of ice, not liquid water, on a glaciated landscape. However, here we are in a “tunnel valley” (Figure 15). This valley is about 0.3 miles wide by 40-60 feet deep. Such valleys typically have undulating (as opposed to concave upward) longitudinal profiles and thresholds within the valleys (Figure 16). In other words, present-day water cannot easily flow down these valleys. Tunnel valleys are often occupied by eskers and drumlins, are oriented parallel to glacial flow, and end near the terminus of ice margins (Kehew & others, 2012). This valley fits most of these criteria.

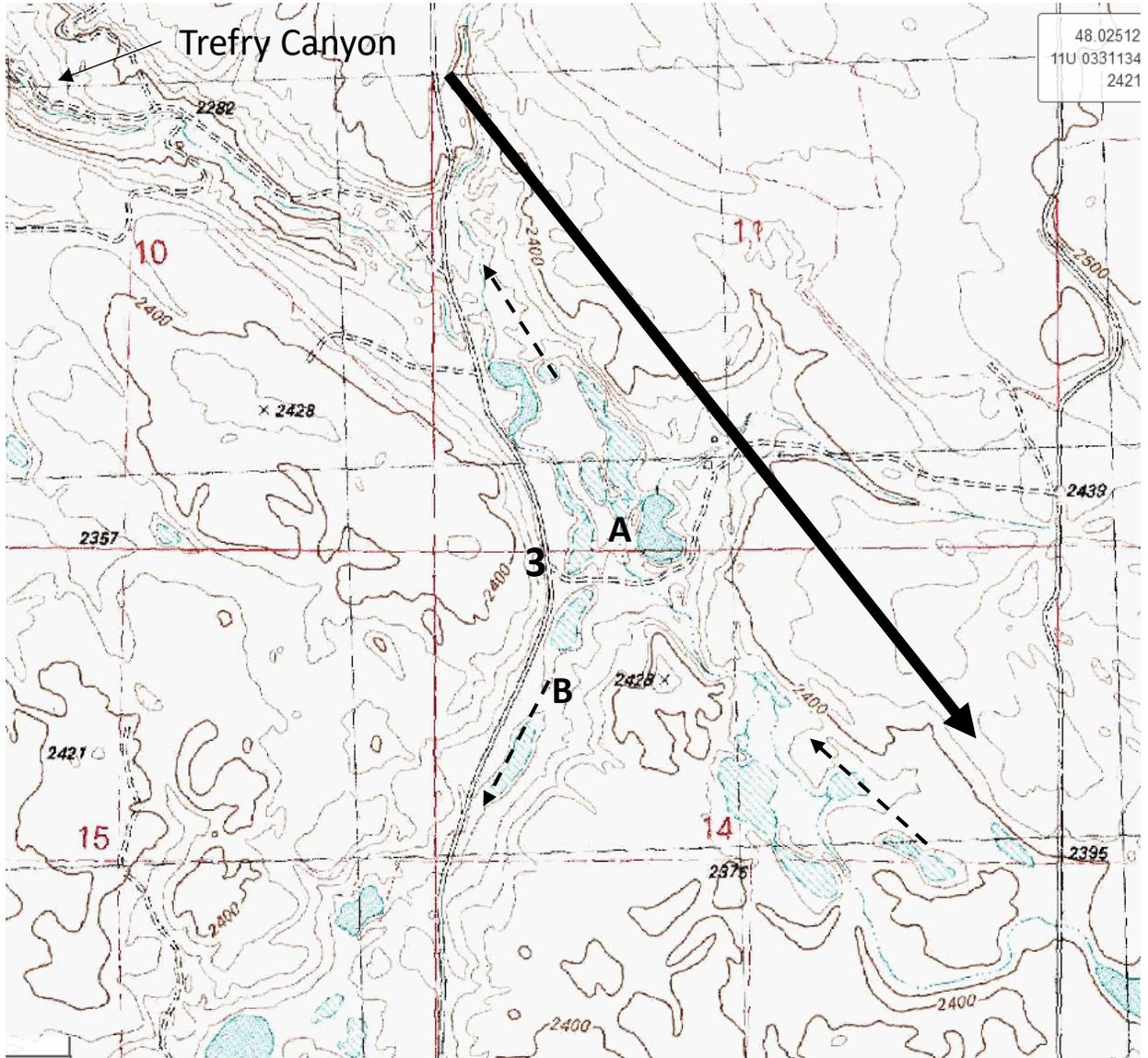
# Stop 3—Near Trefry Canyon



**Figure 15—Oblique aerial view toward the northwest of a tunnel valley and eskers within above Trefry Canyon. Bold number indicates approximate location of Stop 3. Source: Google Earth Pro, 09/13/2011.**

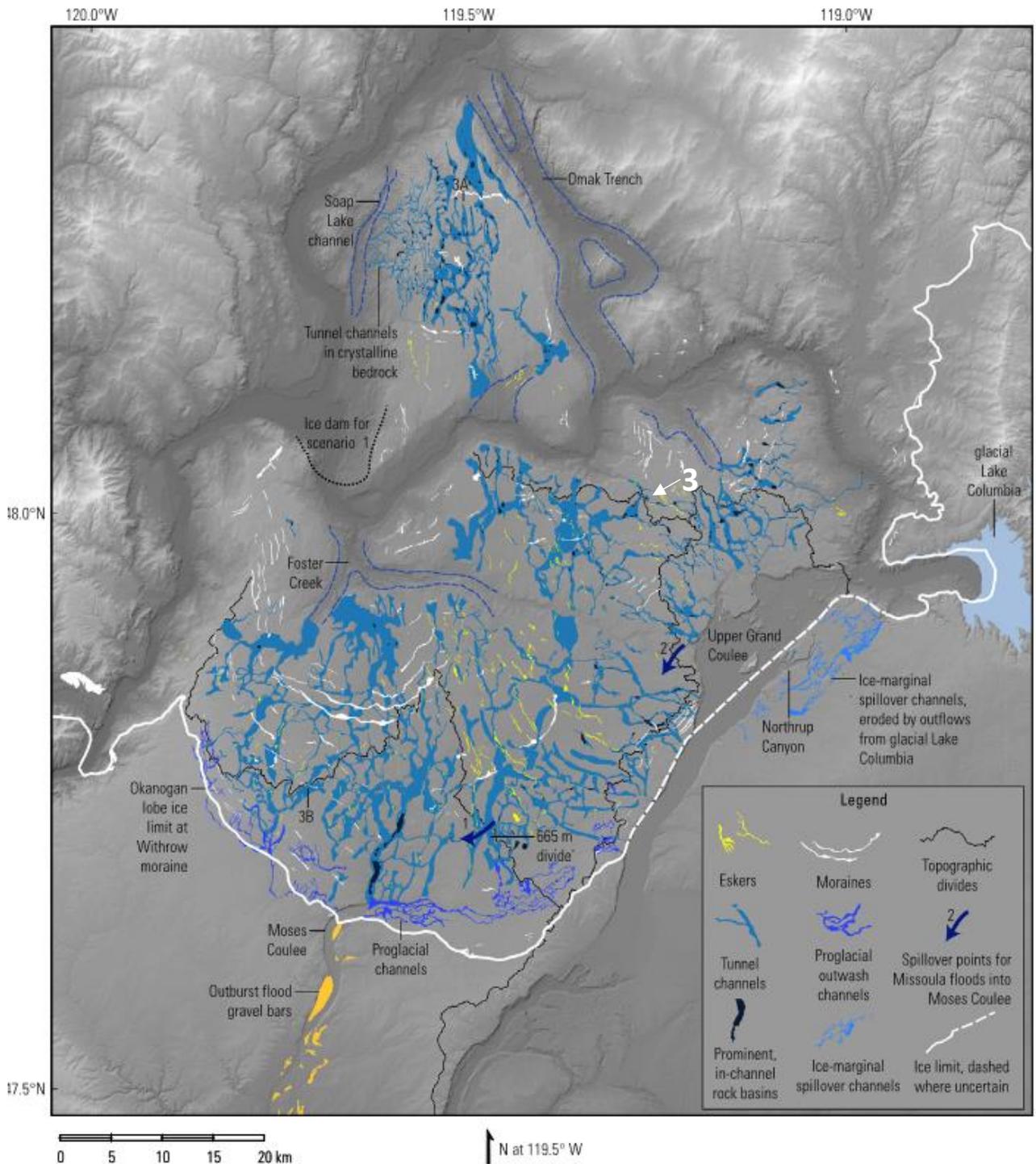
**Tunnel valley origins.** Tunnel valleys are thought to originate beneath ice sheets as a result of subglacial meltwater erosion. Such water may be pressurized by the overlying mass of an ice sheet. This helps explain the fact that such channels may ascend adverse slopes and cross drainage divides. Warm-based ice sheets such as the Okanogan Lobe should have had ample subglacial meltwater that may have periodically released as floods. This combination of pressurized water and floodwater would have been capable of eroding channels in loose sediments as well as basalts and granitics. When examined on a plateau-wide scale, one can see the anastomosed (i.e., multiple, interconnected channels) nature of the channel network (Figure 17) that supports a catastrophic flood origin for tunnel valleys (Gombiner and Lesemann, 2024).

# Stop 3—Near Trefry Canyon



**Figure 16. Tunnel valley hydrology and topography at Stop 3. Blue dashed-dotted line indicates intermittent surface water flow from east to west into Trefry Canyon. However, it is difficult to discern a topographic gradient (small dashed black arrows), especially in the vicinity of A, and at B the topographic gradient hence flow direction is reversed. Bold arrow indicates ice advance direction. Bold number indicates approximate parking location of Stop 3. North is toward the top of the map. Trefry Canyon, WA 7.5' USGS topographic map. Source: Caltopo.com**

# Stop 3—Near Trefry Canyon

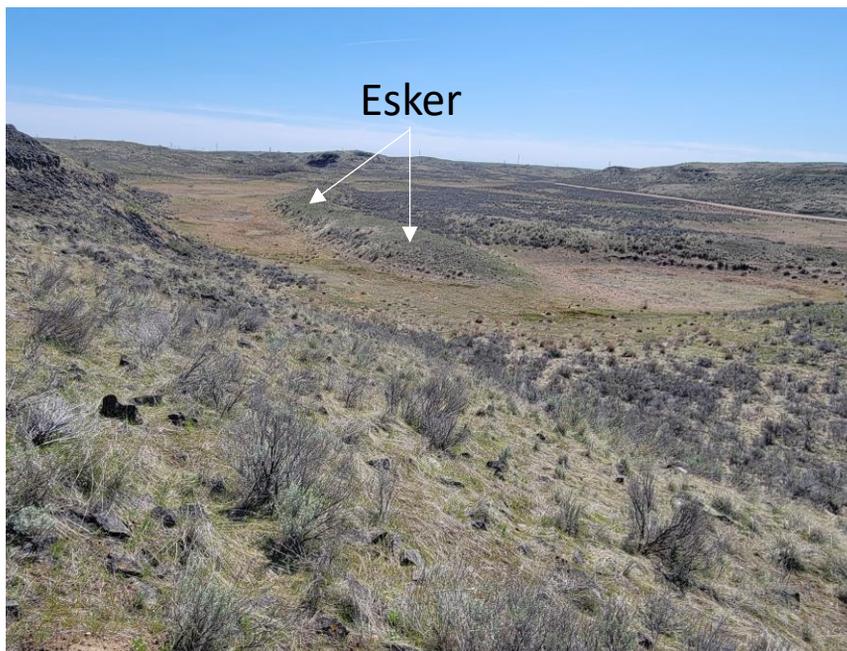


**Figure 17. Tunnel channels, in-channel rock basins, proglacial channels, eskers, recessional moraines, and topographic divides on Waterville and Omak plateaus. Bold number indicates approximate location of Stop 3. Source: Gombiner and Lesemann (2024).**

# Stop 3—Near Trefry Canyon

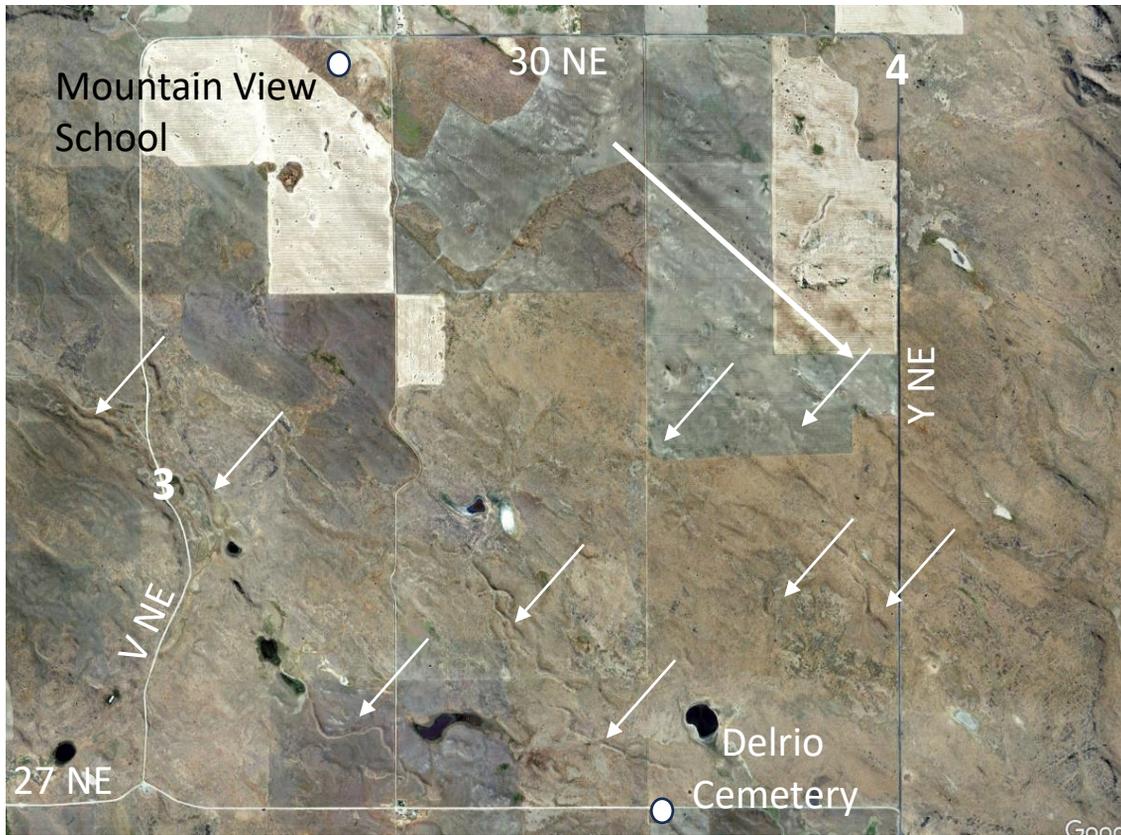
**Eskers.** The sinuous ridge in the bottom of this valley is an “esker” (Figure 18). Eskers are channel fillings formed by subglacial water at the base of glacial ice (Figure 11). As channel fillings, they are composed of size sorted and stratified (i.e., layered) sands and gravels. Eskers in the area often terminate at recessional moraines or fans/deltas (Hanson, 1970). This esker is short (~0.5 mile long) by Waterville Plateau standards. One near Sims Corner to the south of here measures over 5 miles long! The presence of eskers on this valley floor indicates that they formed after the formation of the valley.

**Implications of stagnant ice features.** Eskers are one example of stagnant ice features. The two eskers within this tunnel valley are among at least ten within three miles of Stop 3 (Figures 15, 18 & 19). These features suggest that the Okanogan Lobe stagnated for a significant period here (Freeman, 1933). The preservation of these eskers indicates that the ice sheet did not readvance after their deposition or they would have been destroyed. Instead, the eskers are “like great dying serpents that give their final testimony to the stagnation of the Okanogan Lobe” (Easterbrook and Rahm, 1970, p. 132 ). In addition to their unique shapes, eskers are tremendous economic resources here and in other stagnant ice areas. They can often be identified by the gravel and sand quarries (like the one near here) (Figure 15) on their surfaces.



**Figure 18. Ground view of esker in tunnel valley at Stop 3. View to south. Source: author photo, 11 April 2025.**

# Stop 3—Near Trefry Canyon

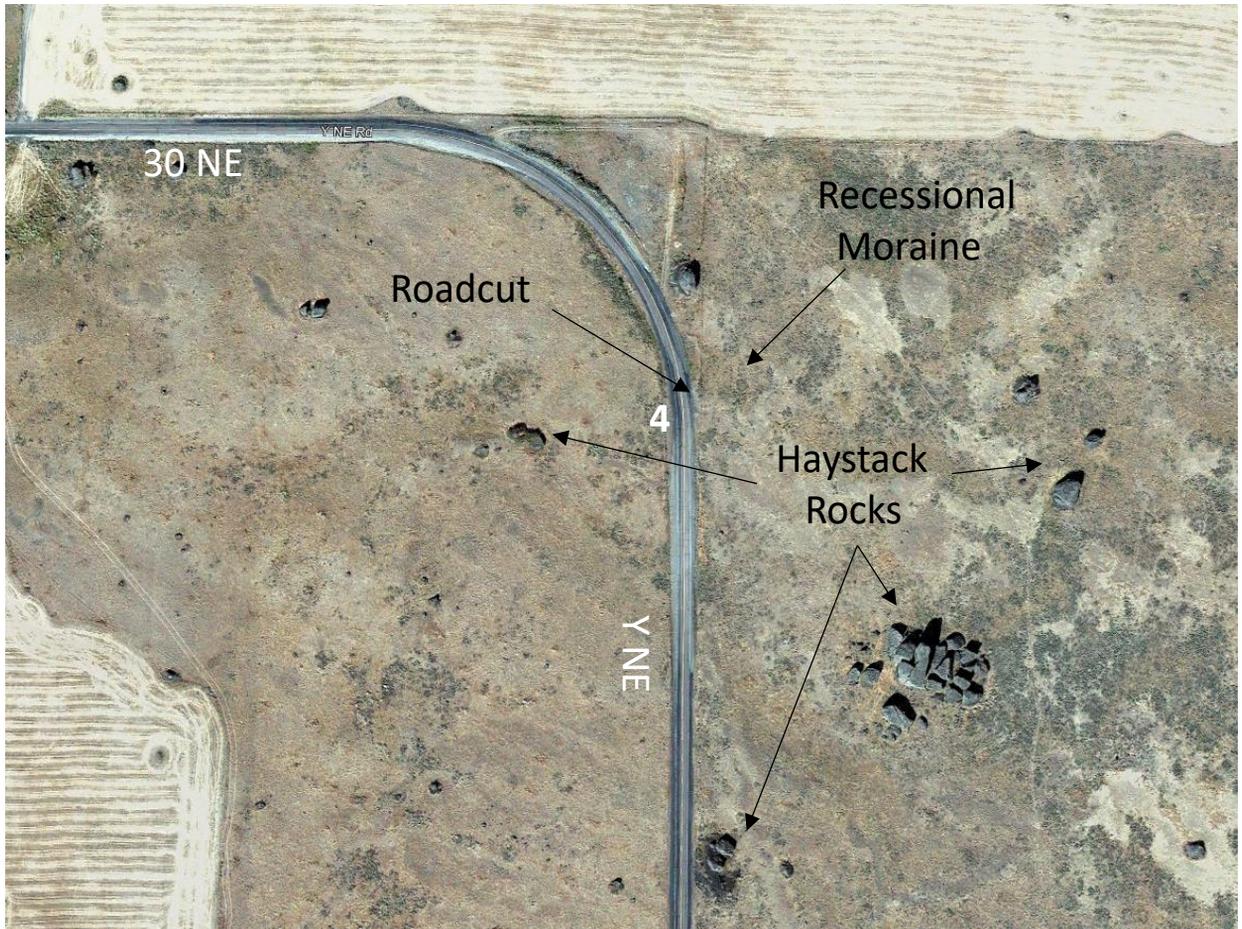


**Figure 19.** Vertical aerial view of stops 3 and 4, and the surrounding lands. Note the prominent eskers (light arrows) to the east, northeast, and southeast of Stop 3. Also, note the NW to SE trend of flutes and drumlins (bold arrow) reflecting the direction of glacial advance in the area. Compare to Figure 13 for the entire Waterville Plateau. North is toward top of image. Source: Google Earth Pro, 04/18/2021.

## Enroute to Stop 4

**Route.** Continue north on road V NE for about 2 miles. The road bends to the east and become 30 NE. In 1 mile, the old Mountain View school house sits at the southwest corner of the junction of roads 30 NE and W NE (Figures 14 & 19). This school operated intermittently from 1906 to 1943 (McGrath, 1989). Continue east on this now paved road 30 NE (also called McCabe Oil) for another 2 miles to Osborne Corner. Note the distinctive “haystack rocks” on the skyline. The road rounds a corner and bends to the south where it becomes road Y NE (but still McCabe Oil). Park on the shoulder of this paved road just after the road bend taking care to be outside the white line (Figures 1 & 21). The GPS coordinates here are: 48.047242°N & 119.213024°W.

# Stop 4—East of Osborne Corner



**Stop 20. “Haystack rocks” east of Osborne Corner. Bold number indicates approximate location of parking for Stop 4. North is toward top of image. Source: Google Earth Pro, 09/13/2011.**

**Location.** At Osborne Corner ([Figure 20](#)), we will first examine a road cut on the east side of the road, then cross the fence onto Washington state land to examine ridges and “haystack rocks”.

**Recessional Moraines.** The sediments here range from from clay- to boulder-size, and are mixed together in a non-layered pile. Because of this, we say they are unsorted and unstratified. These are key characteristics of glacial “till” deposited directly by a glacier. The till composes a low ridge that appears to be part of a small recessional moraine formed during a pause in the retreat of the Okanogan Lobe ([Figure 21](#)). This ridge is one of at least five such moraines that we crossed between Stop 3 and 4 ([Figure 21](#)) suggesting at least five stillstands during ice retreat.

# Stop 4—East of Osborne Corner

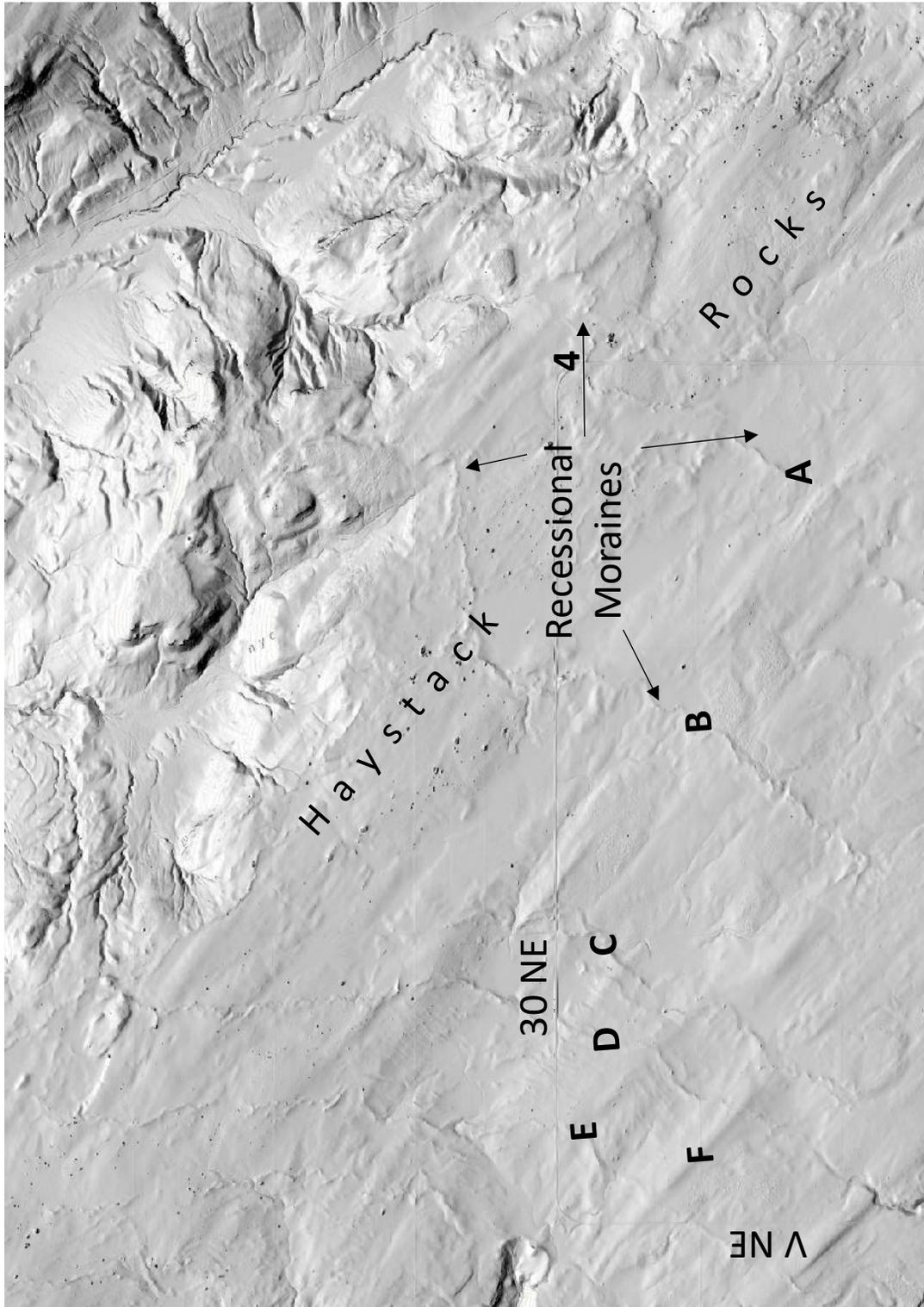


Figure 21. Recessional moraines and haystack rocks in vicinity of Osborne Corner (4). Note recessional moraines (A-E) oriented perpendicular to flutes and drumlins (F) that represent overall ice advance direction. Also, note northwest to southeast trend of haystack rocks that parallel orientation of flutes and drumlins. North is toward top of image. Source: Washington Lidar Portal.

# Stop 4—East of Osborne Corner

**Haystack rocks.** The large rocks here have long been called “haystack rocks” because of their similarity to the hand-piled haystacks of the past (Figure 22). These large boulders, like thousands of others on the Waterville Plateau, were likely “plucked” by the Okanogan Lobe from nearby, underlying basalt bedrock, transported in or on the ice, then deposited here as ice melted. When advancing glacial ice temporarily froze to the underlying bedrock, large chunks of rock were plucked from the bedrock surface. Plucking was enhanced by jointing (i.e., fractures) in bedrock. Basalt is notorious for its jointing patterns (Figure 23) and these joints enabled the Okanogan Lobe and Ice Age floods to pluck the bedrock surface. The layered Columbia River Basalts that form the boundary of the Waterville Plateau were an ideal place for glacial plucking as the ice sheet advanced over it (e.g., Russell, 1893; Waters, 1933). The weak interbeds separating the different flows may have also enhanced the plucking of large boulders (Hanson, 1970). As with Ice Age flood-related plucking, one would expect that columnar joints are more readily plucked than the entablature jointing. However, I would expect that the entablature would better survive ice transport. The large haystack rocks here appear to be entablature.

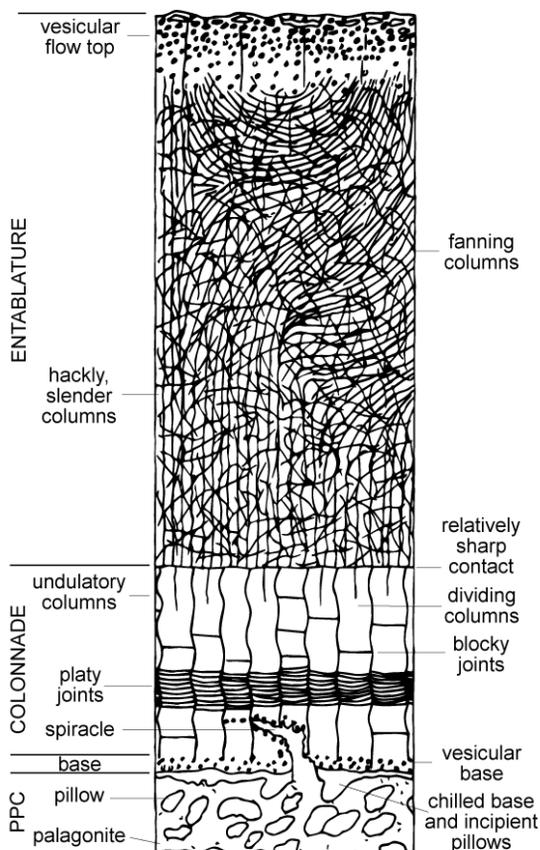
Some geologists and geographers would also refer to this as an “erratic”—i.e., a boulder that was transported here from elsewhere by glacial ice. Others would say that an erratic needs to be different in composition from the underlying rock. In that case, this is not an erratic as the area is immediately underlain by basalt bedrock. However, you don’t have to look far to find true erratics—i.e., granite and granodiorite boulders—here. The relative numbers of these compared to the ample basalts reinforces the idea that basalts are easier to pluck.

What is impressive about the haystack rocks at this stop is not only their size but also their grouping. Why were they deposited in such a large group? These are too large to have been moved by humans. What is it about the glacial ice that led to such an accumulation of rocks? These rocks are also impressive in their linear distribution across this part of the plateau helping create a distinctive skyline. You may have noticed this on the drive from Stop 3 to Stop 4. That linear pattern extends at least 8 miles from the edge of the basalts southeast to the Strahl Canyon Road (Figure 21).

# Stop 4—East of Osborne Corner



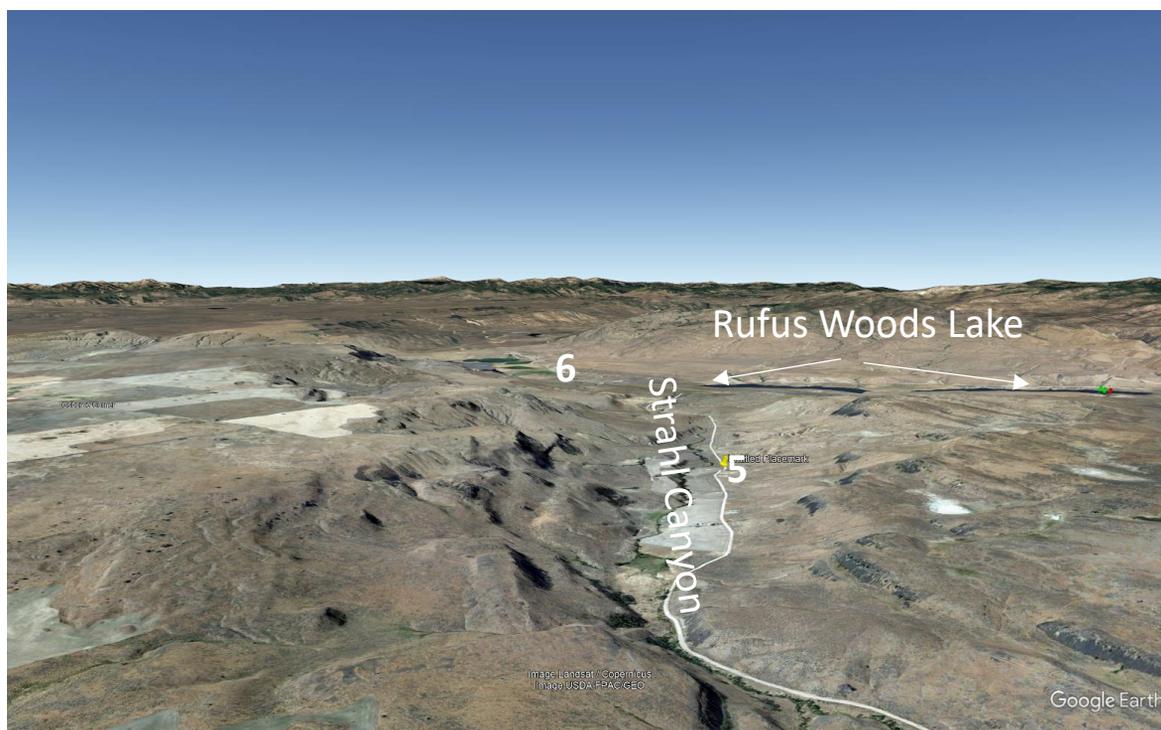
**Figure 22.** Haystack rocks east of Osborne Corner. Largest basalt boulder here (locally known as “balloon rock”) measures approximately 50 ft wide by 40 ft tall. Note entablature. Source: author, 11/18/2024.



**Figure 23.** Typical cross section of a Columbia River Basalt flow. Note the different jointing patterns. Source: <https://www.dnr.wa.gov/programs-and-services/geology/explore-popular-geology/geologic-provinces-washington/columbia-basin>

# Enroute to Stop 5

**Route.** From here, continue south on road 30 NE (i.e., McCabe Oil Rd) south for about 5.5 miles to WA 174. Turn left onto WA 174 and head east ~2 miles to Strahl Canyon Road. Follow this good gravel road as it meanders north. At an unmarked intersection with another good gravel road at about 4 miles continue north (or left). Do the same less than 0.5 miles later. You are on track if you descend into Strahl Canyon. right—remain on this road. At about 7.5 miles from WA 174, there will be a road cut on the right (east) side of the road. Park on the side of the road near that road cut taking care to provide passing vehicles ample room ([Figure 25](#)). GPS coordinates: 48.062389° & 119.192299°



**Figure 24.** Oblique aerial view to the northwest of Stops 5 & 6. Stop 5 is situated near the bottom of Strahl Canyon and Stop 6 is downriver of the canyon's mouth. Note the proximity of all to Rufus Woods Lake (i.e., Columbia River). Source: Google Earth Pro, 04/18/2021

## Stop 5--Strahl Canyon

**Location.** We are located in Strahl Canyon at an elevation of about 1800 ft ([Figure 24](#)). We will remain on the road here.

# Stop 5--Strahl Canyon

**Strahl Canyon & glacial meltwater.** Strahl Canyon is a prominent north- northwest trending canyon eroded in basalts and draining the northeastern Waterville Plateau (Figure 24). Near its mouth, it is nearly 3 miles wide and 900 feet deep. The canyon's size is perplexing given the relatively small drainage basin feeding it. Did it form from glacial meltwater exiting the Waterville Plateau northward? If so, did it form during an earlier glaciation that has since been partially obscured by subsequent erosion and deposition of glacial drift. Such deposition could change a drainage area. Did Strahl Canyon initially funnel outburst floods from the Omak Trench into the Grand Coulee via Barker Canyon? We still have lots of questions here.

**Glacial Lake Columbia sediments.** The sediments in the road cut here were deposited in Strahl Canyon by Glacial Lake Columbia (Figure 25). Suspended sediments transported into the glacial lake by the Columbia River and its tributaries settled in its quiet waters. This resulted in "couplets"--i.e., pairs of layers-- representing seasonal changes in deposition or ice age flood impacts on deposition. The lake sediments here are overlain by windblown "loess" that likely originated from glacial outwash in the last ~11,000 years (i.e., Holocene).

**Terraces.** As the Okanogan Lobe downwasted during deglaciation, the lake dropped from at least 2,400 ft elevation (Hibbert, 1985) to successively lower levels. Terraces formed where the lake persisted for a significant period before dropping further. A terrace is visible at about 2,025 ft in this canyon. The 1,750 ft terrace across the canyon is composed of glacial Lake Columbia sediments (Figure 26). I count four below us to Rufus Woods Lake--~1,660 ft, ~1,300 ft, ~1,210 ft, and ~1,060 ft.

**Mass wasting & Landslides.** "Mass wasting" (i.e., gravity-induced movements of bedrock and sediment) has occurred here in a variety of forms over time. A common form of mass wasting is a landslide. Past studies in the area have shown mass wasting to occur on basalt edges (e.g., Eckerlin, 1989). Landslides are indicated by prominent scarps above large, bedrock blocks. Such landslides are common on the steep edges of Columbia River Basalts because of the presence of weak zones within the basalts (e.g., transition from colonnade to entablature) and between the basalts (i.e., sedimentary interbeds). Slides and flows also occur in the weak "Quaternary" (i.e., past ~2.6 million years) sediments that are present on the valley walls (Jones & others, 1961). Slides and flows were enhanced by wetter climates that "lubricated" weak layers. Slide may also occur because of undercutting by floods (prehistoric and historic). Therefore, mass wasting in the area may range from pre-Quaternary and inactive to recent and active.

Two large landslides are present on the western edge of Strahl Canyon in the vicinity of Stop 5 (Figure 27). These slides occurred in the Columbia River Basalts and are mantled by glacial till and large erratics. Therefore, they are pre-glacial or at least, pre-last glacial.

# Stop 5—Strahl Canyon



**Figure 25. Glacial Lake Columbia sediments in roadcut at Stop 5 at ~1740 ft elevation. Note horizontal bedding and numerous rhythmites that may represent annual deposition or floods into the lake. Source: author photo, 04/11/2025.**



**Figure 26. View downvalley from above Stop 5 (to the northwest at the ~1,750 ft glacial Lake Columbia terrace. Also, note the landslide near the mouth of Strahl Canyon. Source: author photo, 11/18/2024.**

# Stop 5—Strahl Canyon



**Figure 27. Oblique aerial view of large landslides (outlined in red) in Columbia River Basalts on the western edge of Strahl Canyon in the vicinity of Stop 5. Note the smooth mantle of glacial drift and the dark specks that are large glacial erratics atop the landslides. Bold number indicates approximate location of Stop 5. View to the west. Source: Google Earth Pro, 09/13/2024.**

## Enroute to Stop 6

**Route.** Continue down the Strahl Canyon Road for about 2.4 miles to its junction with an unmarked, prominent good gravel road that goes off the left (road 32 NE. Turn left onto this Douglas County road and proceed northwest (and downriver) for about 2.3 miles to Stop 6. A small side road heading toward the river is present here but we will park along the side of road 32 NE (Figure 25). This stop provides us with an excellent overlook of the Columbia River. GPS coordinates: 48.099195°N & 119.267486°W.

## Stop 6—Columbia River Overlook

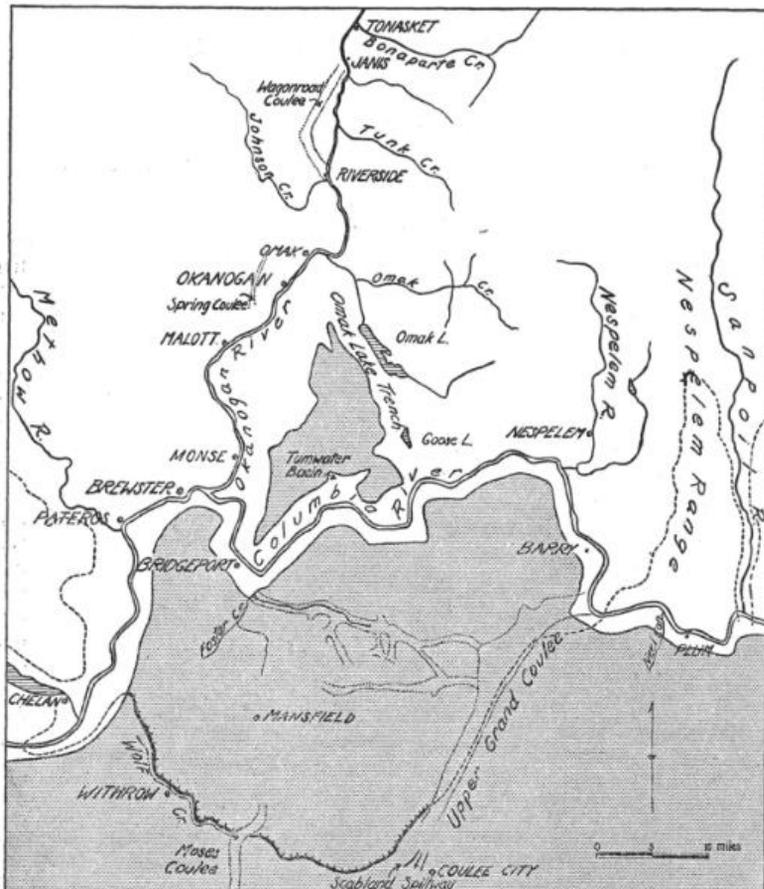
**Location.** We are located above the Columbia River (now Rufus Woods Lake) on west of Alameda Flat (Figure 25). We will walk out onto an overlook of the Columbia River on U.S. government land.

# Stop 6—Columbia River Overlook

**Changing paths of Columbia River.** The upper Columbia River originates in the Rocky Mountains of British Columbia, Washington, Idaho, and Montana. Because it originates in high, mid-latitude mountains, the river's flow depends largely on snowmelt. As a result, the flow varies throughout the year.

The flow of the Columbia River was shaped by late Pleistocene floodwaters from the Clark Fork River (Missoula Floods) (e.g., Bretz, 1969). And, as noted above, these flows were diverted by the Okanogan Lobe over the Waterville Plateau to form the Grand Coulee.

Bedrock geology and the Okanogan Lobe also shaped the path of the Columbia River here. As the Columbia River flowed west from the mouth of the Spokane River, it generally followed the northern edge of the Columbia River Basalts (Figure 28) (Willis, 1887). A lobe of basalts extends north from here. Geologists (e.g., Willis, 1887; Pardee, 1918; Flint, 1935) suggest that the Columbia River once followed the edge of this lobe northward creating an ~18 mile long valley (i.e., the Omak Trench) (Figure 29) to the vicinity of present-day Omak. The Columbia River merged with the Okanogan River there and flowed south.



**Figure 28. Columbia River in relation to the Columbia River Basalts (dark shade). Bold number indicates approximate location of Stop 2. Source: Flint (1935, p. 170).**

# Stop 6—Columbia River Overlook

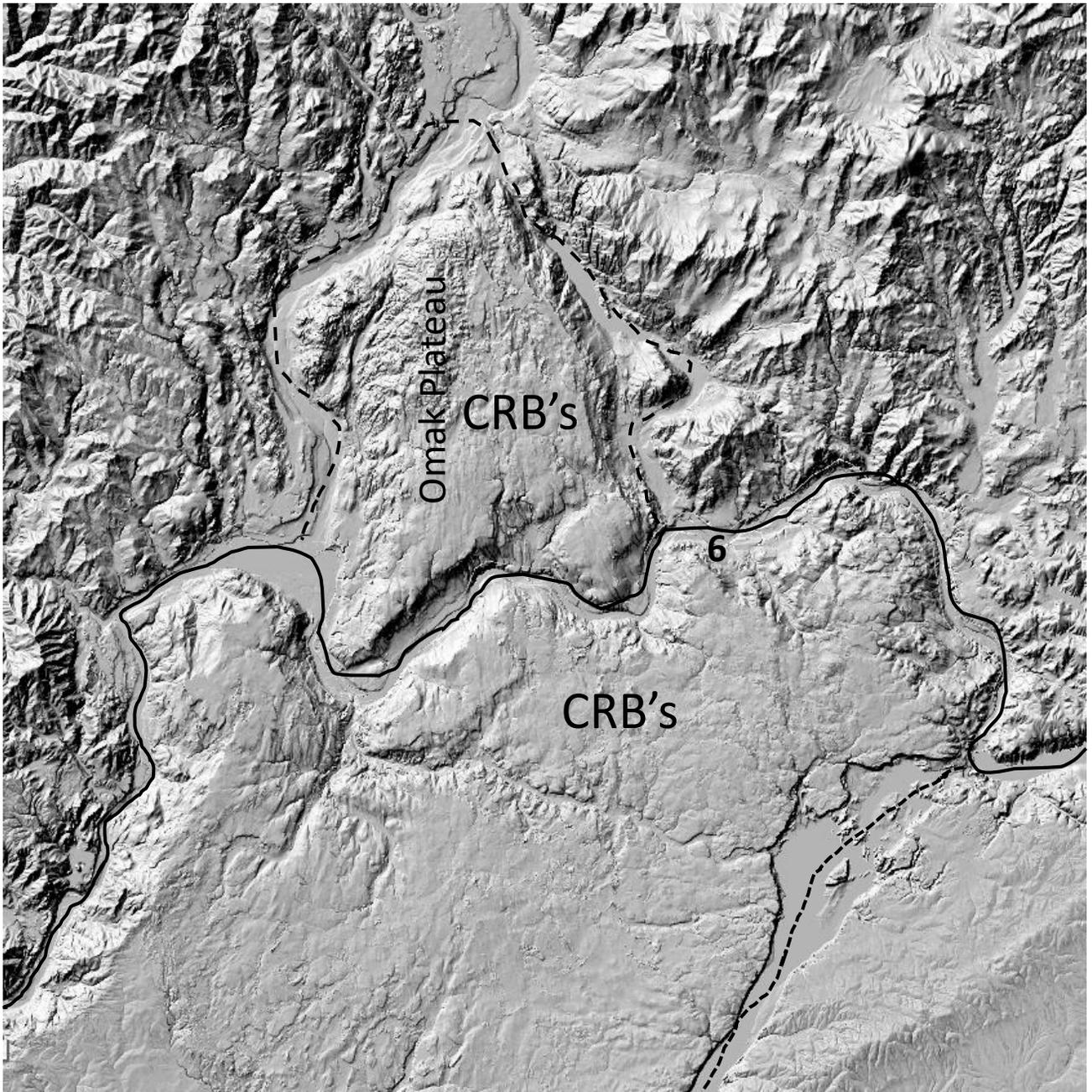


**Figure 29. View of the mouth of the Omak Trench, an earlier pathway of the Columbia River. Source: Author photo, 04/11/2025.**

**Changing paths of Columbia River** (continued)...So, why did the Columbia River's path change to its current form (**Figures 29 & 30**)? With the advance of the Okanogan Lobe, the Omak Trench path was blocked by ice therefore pushing the Columbia River to the south. The river, perhaps aided by Missoula Floods, excavated a west-trending channel roughly parallel to the ice front (Flint, 1935). Because this channel was incised below the level of the southern entrance of the Omak Trench, the Columbia River has remained in this reach in post-glacial times.

**Crossing the Columbia River.** Perhaps as much as this was a place to settle, it was also a place to pass through, especially to points north. Mines in British Columbia and later, on the Moses Reservation, drove this need. Travelers came up the Upper Grand Coulee and exited via Barker Canyon. Most turned west and headed down Foster Creek to cross the Columbia River near present-day Bridgeport (Anglin, 1995, p. 100) (**Figure 31**). However, some took a more direct route to the north and northeast to cross the Columbia River (**Figure 31**). Strahl Canyon (our previous stop) was part of this more direct route.

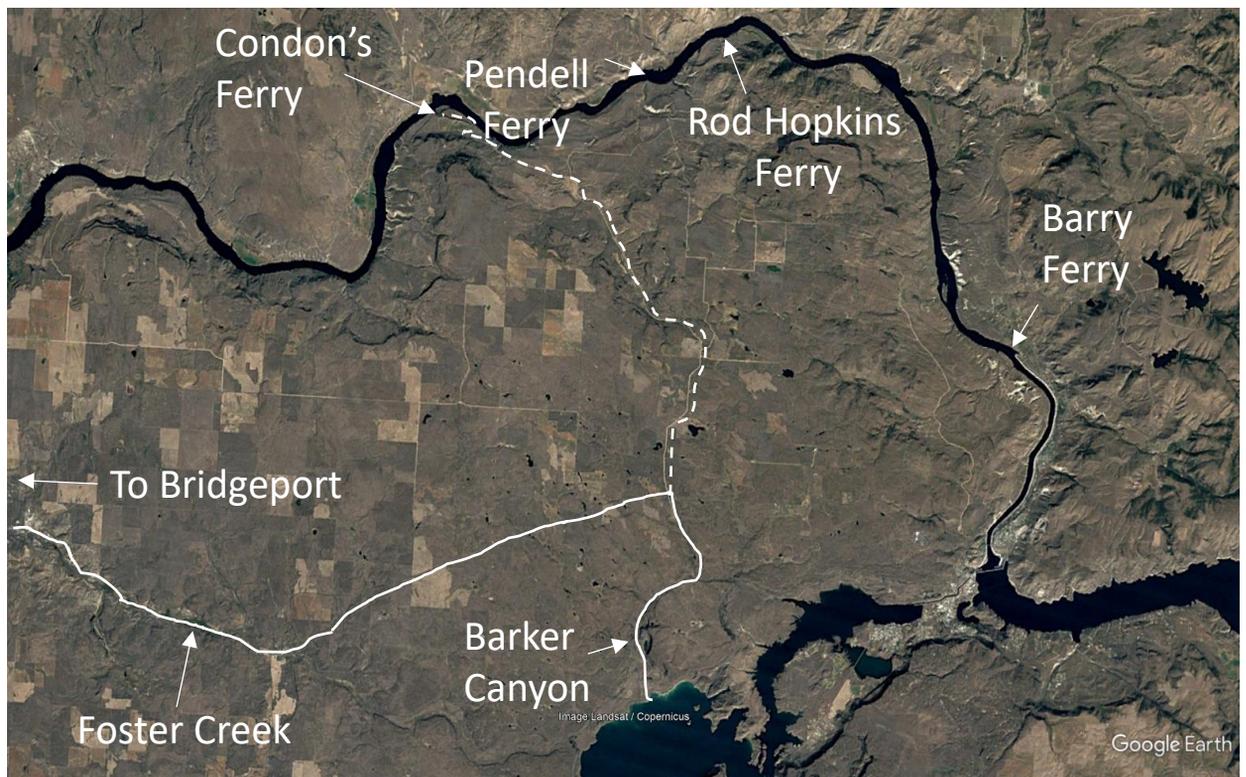
# Stop 6—Columbia River Overlook



**Figure 30. Current path of Columbia River (solid line), late Pleistocene Grand Coulee path of the Columbia River (dotted), and late Pleistocene path of Columbia River (dashed). Bold number indicates approximate location of Stop 6. Source: Caltopo.com.**

# Stop 6—Columbia River Overlook

**Crossing the Columbia River (continued)**...In the ~36 mile stretch of the Columbia River that borders the northeastern Waterville Plateau, four ferries—Condon, Pendell, Rod Hopkins, and Barry (Ruby & Brown, 1974) operated at various times here (Figure 31). The Condon Ferry ran the longest, from the early 1860's until 1931 (Ruby and Brown, 1974; Anglin, 1995). This ferry started as logs or canoes lashed together to form a raft and by the mid-1880's evolved to a barge-like structure with a windlass and cable. It was part of a stage route so it included a stage stop as well as hotel, saloon, blacksmith shop, and livery stable (Rabideau, 1976, p. 268) (Figure 32). At least one of these ferries—Barry—originated where Indians had swam their horses across the river for years (Ruby and Brown, 1974). Ferries carried anything that needed transporting from people to farm equipment to cattle. The Rod Hopkins ferry was considered to be an out-of-the-way place that was known for transporting stolen livestock. *“Such nefarious activity was of interstate and international proportions. Stolen Canadian horses found eventual homes in Oregon and vice versa. It was also a good place for crossing Canadian liquor smuggled into the state during Prohibition days (Ruby and Brown, 1974, p. 139)*



**Figure 31. Two routes from the Grand Coulee to the north. Solid line is the most common Foster Creek route. The dashed line represents the Strahl Canyon route to Condon's Ferry. Source: Google Earth Pro, 12/30/2010.**

# Stop 6—Columbia River Overlook



**Figure 32. Early version of Condon Ferry and a wagon loaded onto it in 1880's. View looking south toward the Douglas County side of the Columbia River at the various buildings at Condon Ferry. Source: Washington State University Libraries Digital Collections (<https://cdm16866.contentdm.oclc.org/digital/collection/cullwhite/id/206/rec/3>), Cull A. White Photographs.**

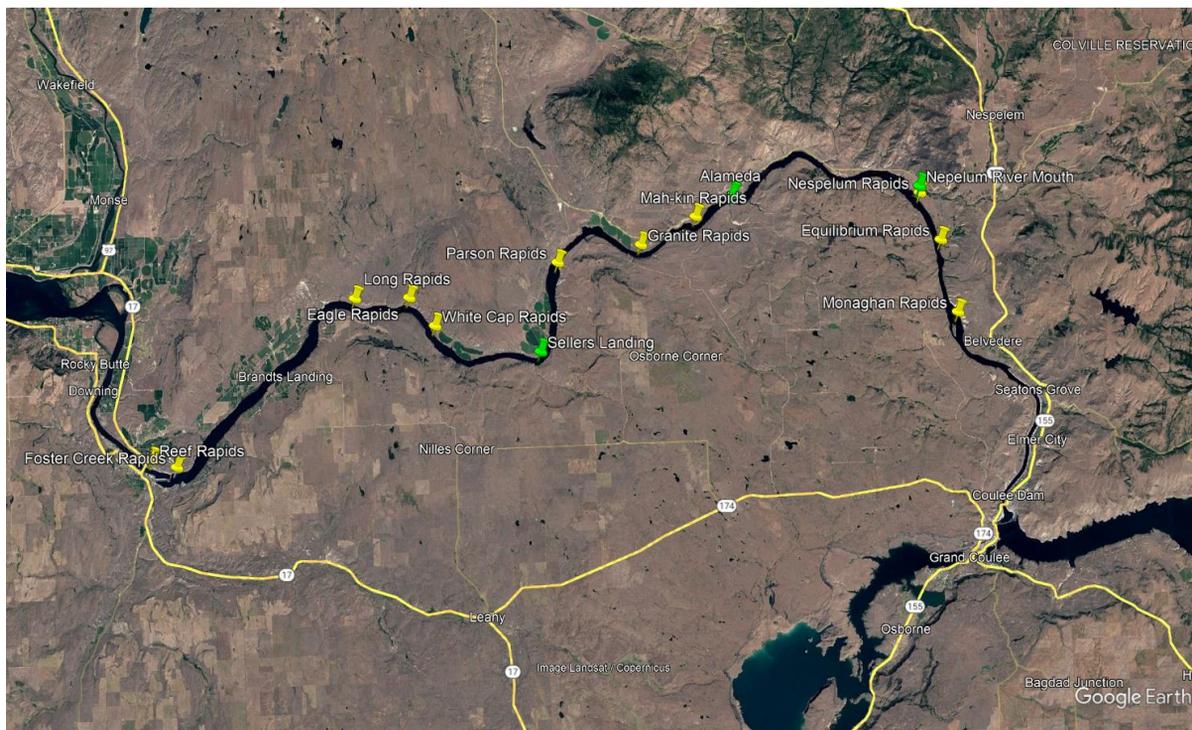
**River Transport and Rapids.** Humans have long used the Columbia River to transport goods. Native Americans moved up and down the river via canoes. Later, Hudson's Bay Company members hauled furs to Fort Okanogan and Fort Vancouver in bateaus including large York boats that were rowed and could take up to 3 tons of cargo (Anglin, 1995). With Euroamerican settlement on the Waterville Plateau, there was a need to transport goods down and up the river.

Prior to river modification by Euroamericans, eleven distinct sets of rapids occurred between present-day Coulee Dam to Bridgeport (**Figure 33**). Over the 45 miles from Monaghan Rapids to Foster Creek Rapids, the river fell 171 feet at low-water. More troubling were the numerous large rocks (many likely glacial erratics) in the river. Based on a trip down the river in early Fall 1881, Thomas Symons of the U.S. Army Corps of Engineers described the river in this reach as "very swift and studded with rocks, and taken all in all will be found an extremely hard and dangerous if not absolutely impassable portion of the river to navigate". Regarding the possibility of navigating this reach with larger

# Stop 6—Columbia River Overlook

**River Transport and Rapids** (continued)... boats, the Corps said “The fall of the river here is so great that it is certain that no system of rock removal could make the river sufficiently navigable to justify the danger and risk necessarily incurred in running boats on it” (*USACE, 1893, p. 3388*). Symons (1967, p. 34-35) summarizes by saying: “this portion of the river through which we have come today is the worst on the whole river, the most complete bar to navigation.” Further, he predicted that “a steamer could come down through this stretch of river, but at considerable risk; I doubt very much if a steamer could get up through it except at great expense, time, and risk.”

Despite this prediction, steamboats reportedly made it to Long Rapids (**Figure 33**), Sellers Landing (**Figures 33 & 34**), and even Alameda and the mouth of the Nespelum River (**Figure 33**). The USACE performed river “improvement” projects that may have permitted this travel. A key reason steamboats were important here was for hauling sacks of wheat to markets downriver River (Rinker, 1976b, p. 82). By about 1920, it was more economical for farmers to haul their wheat to Coulee City via the Grand Coulee road then have it hauled to markets by the railroad (Rinker, 1976b).



**Figure 33. Major Columbia River rapids and steamboat landings on the Columbia River between Coulee Dam and Bridgeport. Sources: US Army Corps of Engineers, 1893; Bridgeport (1957), Boot Mountain (1950), Alameda Flat (1950), Nespelem (1950), and Grand Coulee (1948) U.S.G.S 15' topographic maps; Symons, 1967; and Layman, 2002.**

# Stop 6—Columbia River Overlook



Figure 34. Unknown steamboat ascending upper Long Rapids, about 8 miles west of Stop 6 in early 20<sup>th</sup> century. Source: [https://upload.wikimedia.org/wikipedia/commons/8/81/Upper Long Rapids%2C Columbia River - NARA - 298825.jpg](https://upload.wikimedia.org/wikipedia/commons/8/81/Upper_Long_Rapids%2C_Columbia_River_-_NARA_-_298825.jpg) from National Archives and Records Admin., Record Group 77: Records of Office of Chief of Engineers, 1789 – 1999.



Figure 35. Steamboat S.S. Delrio at Sellers (Landing?), upper Columbia River sometime between 1915 and 1922. Source: Washington State Historical Museum, catalog ID: 2000.176.133, call number: 2000.176.133, [https://www.washingtonhistory.org/research/collection-item/?search\\_term=delrio&search\\_params=search\\_term%253Ddelrio&irn=58816](https://www.washingtonhistory.org/research/collection-item/?search_term=delrio&search_params=search_term%253Ddelrio&irn=58816)

# Stop 6—Columbia River Overlook

**Recent Potential Human Uses.** At least five bombing and strafing ranges were established on the Waterville Plateau during World War II. You can learn more about these in the East of Moses Coulee field trip (<https://www.cwu.edu/academics/geography/documents/east-of-moses-coulee-field-trip-09-19-2023.pdf>). The establishment of such bombing and strafing ranges during World War II seems reasonable given the state of the world in the 1940's and the sparse population of the plateau. However, the U.S. Navy proposed in 1974 to use 5,900 acres (9.2 mi<sup>2</sup>) of the northern Waterville Plateau as a target training range. Given the size of the proposed range and that another 33,000 acres (51.6 mi<sup>2</sup>) would have been subject to restrictions, this would have impacted 30 families living in the area (Rinker, 1976c). Local farmers worked with members of Congress to squash the idea (Lee Hemmer, oral communication, 07/2023)

## Wrapping Up & Returning Home

Today, we have travelled across the glaciated terrain of the northeastern Waterville Plateau and into the glaciated and glacial lake-covered Columbia River Valley. Enroute, we have explored landscapes on two different geologic formations in a semiarid setting. We have seen the impacts of pre-glacial landslides, glacial advance, glacial stagnation, and subglacial floods. We have also seen a human landscape that has changed dramatically with the influx and subsequent exodus of Euroamericans.

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 financial support. Feel free to contact me at [lillquis@cwu.edu](mailto:lillquis@cwu.edu) or (509) 963 1184 if you have further questions/comments. I hope to see you on the next trip in September 2025. To get back to WA 174...*Return to the junction of 32 Rd NE and Strahl Canyon Road. Turn right onto Strahl Canyon Road and follow nearly 10 miles back to WA 174. At WA 174, you may choose to go left (east) to Grand Coulee or right (west) to Leahy Junction. If you go to Leahy Junction, you may then head west toward Bridgeport or south toward Coulee City on WA 17.*

# References Cited

- Anglin, R. 1995. *Forgotten Trails: Historical Sources of the Columbia's Big Bend Country*. WSU Press.
- Baker, V.R., B.N. Bjornstad, D.R. Gaylord, G.A., Smith, G.A., S.E. Meyer, P. Alho, R.M. Breckenridge, M.R. Sweeney, M.R. & M. Zreda. 2016, Pleistocene megaflood landscapes of the Channeled Scabland, in Lewis, R.S., and Schmidt, K.L., eds., *Exploring the Geology of the Inland Northwest*. Geological Society of America Field Guide 41, p. 1–73.
- Benn, D.I. & D.J.A. Evans. 1998. *Glaciers and Glaciation*. Arnold. London.
- Booth, D.B., K.G. Troost, J.J. Clague & R.B. Waitt. 2003. The Cordilleran Icesheet. *Development in Quaternary Science* 1: 17-43.
- Bretz, J H. 1923. Glacial drainage on the Columbia Plateau. *Geol. Soc. of America Bull.* 34: 573-608.
- Bretz, J H. 1969. The lake Missoula floods and the channeled scabland. *Journal of Geology* 77: 505-543.
- Clague, J.J. and T.S. James. 2002. History and isostatic effects of the last ice sheet in southern British Columbia. *Quaternary Science Reviews* 21(1): 71-87.
- Donaldson, W.R. and C. Ruscha. 1975. Washington Climate for Chelan, Douglas and Okanogan Counties. Cooperative Extension Service, Washington State University, EM 3889.
- Easterbrook, D.J. and D.A. Rahm. 1970. Landforms of Washington: The Geologic Environment. Western Washington State College, Bellingham.
- Eckerlin, R.D. 1989. The Bridgeport Slide, North-Central Washington. Pp. 921-926 in R.W. Galster, Chairman, *Engineering Geology in Washington*. Volume 2. Washington Division of Geology and Earth Resources Bulletin 78.
- Flint, R.F. 1935. Glacial features of the southern Okanogan region. Geological Society of America Bulletin 47: 169-194.
- Freeman, O.W. 1933. Stagnation of the Okanogan Lobe of the Cordilleran Ice Sheet and the resulting physiographic effects. *Northwest Science* 7: 61-66.
- Gombiner, J. 2022. The Okanogan Lobe and Moses Coulee During the Last Glaciation. PhD Dissertation, University of Washington.
- Gombiner, J. & J. Lesemann. 2024. Okanogan lobe tunnel channels and subglacial floods into Moses Coulee. Channeled Scabland, northwestern United States. *Geology* 52 (7): 502-506.
- Gulick C.W. and M.A. Korosec. 1990a. Geologic Map of the Banks Lake 1:100,000 Quadrangle. *Washington Div. of Geology and Earth Resources Open File Report* 90-6.
- Gulick C.W. and M.A. Korosec. 1990b. Geologic Map of the Omak 1:100,000 Quadrangle. *Washington Div. of Geology and Earth Resources Open File Report* 90-12.
- Hanson, L.G. 1970. The Origin and Development of Moses Coulee and Other Scabland Features on the Waterville Plateau, Washington. PhD Dissertation, University of Washington.
- Hibbert, D.M. 1985. Quaternary geology and the history of the landscape along the Columbia between Chief Joseph and Grand Coulee Dams. Pp. 85-111 in S.K., Campbell, ed., *Summary of Results, Chief Joseph Dam Cultural Resources Project, Washington*. Office of Public Archaeology, Institute for Environmental Studies, University of Washington.
- Jones, F.O., D.R. Embody & W.L. Peterson. 1961. Landslides Along the Columbia River Valley Northeastern Washington. *US Geological Survey Professional Paper* 367.
- Kehew, A.E., J.A. Piotrowski & F. Jorgenson. 2012. Tunnel valleys: concepts and controversies—a review. *Earth-Science Reviews* 113: 33-58.
- Kovanen, D.J. & O. Slaymaker. 2004. Glacial imprints of the Okanogan Lobe, southern margin of the Cordilleran Ice Sheet. *Journal of Quaternary Science* 19 (6): 547-565.
- Jones, F.O., D.R. Embody & W.L. Peterson. 1961. Landslides Along the Columbia River Valley Northeastern Washington. *US Geological Survey Professional Paper* 367.

# References Cited (continued)

- Kehew, A.E., J.A. Piotrowski & F. Jorgenson. 2012. Tunnel valleys: concepts and controversies—a review. *Earth-Science Reviews* 113: 33-58.
- Kovanen, D.J. & O. Slaymaker. 2004. Glacial imprints of the Okanogan Lobe, southern margin of the Cordilleran Ice Sheet. *Journal of Quaternary Science* 19 (6): 547-565.
- Layman, W.D. 2002. *Native River: The Columbia Remembered*. WSU Press., Pullman.
- McGrath, M. 1989. *Country Schools*. Empire Publishing, Waterville.
- Ogle, G.O. & Co. 1915. *Standard Atlas of Douglas County, Washington*. Geo. A. Ogle & Co Publishers & Engravers. Chicago.
- Pardee, J.T. 1918. Geology and mineral resources of the Colville Indian Reservation, Washington. *U.S. Geological Survey Bulletin* 677.
- Rabideau, C.J. 1976. Stage stops and old freighter roads. Pp. 268-69 in Seiler, V. *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Assoc.
- Rice, L. and Mr. & Mrs. Roy Rankin. 1976. Memories of homestead days. Pp. 61-62 in Seiler, V., ed., *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Association.
- Rinker, H. 1976a. Early days of the area. Pp. 84-88 in Seiler, V., ed., *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Association.
- Rinker, H. 1976b. Sellers Landing. Pp. 82-83 in Seiler, V., ed., *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Association.
- Rinker, H. 1976c. Farms threatened by bombing range. Pp. 254-55 in Seiler, V., ed., *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Assoc.
- Ruby, R.H. and J.A. Brown. 1974. *Ferryboats on the Columbia River: Including the Bridges and Dams*. Superior Publishing Company. Seattle.
- Russell, I.C. 1893. A geological reconnaissance in Central Washington. *Bulletin of the U.S. Geological Survey* 108.
- Seiler, V. 1976. *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Association.
- Shaw, J. 1983. Drumlin formation related to inverted melt-water erosional marks. *Journal of Glaciology* 29: 461-479.
- Stoffel, K.L., N.L. Joseph, S.Z. Waggoner, C.W. Gulick, M.A. Korosec & B.B. Bunning. 1991. Geologic Map of Washington – Northeast Quadrant. *Washington Division of Geology and Earth Resources Geologic Map GM-39*.
- Symons, T.W. 1967. *The Symons Report on the Upper Columbia River and the Great Plain of the Columbia*. Ye Galleon Press, Fairfield, WA.
- Trefry, Mrs. George. 1976. Church and cemetery. Pp. 60 in Seiler, V. *From Pioneers to Power: Historical Sketches of the Grand Coulee Dam Area*. Grand Coulee Dam Bicentennial Association.
- United States Army Corps of Engineers. 1893. Report of the Chief of Engineers, U.S. Army, Part 4. U.S. Government Printing Office. Pp. 3388-3389, 3394-3396.
- Waitt, R.B., B.F. Atwater, K. Lehnigk, I.J. Larsen, B.N. Bjornstad, M.A. Hanson, J.E. O'Connor. 2021. Upper Grand Coulee: New views of a channeled scabland megafloods enigma. Pp. 1-56 in A.M. Booth and A.L. Grunder. Eds, *From Terranes to Terrains: Geologic Field Guides on the Construction and Destruction of the Pacific Northwest*. Geological Society of America Field Guide 62.
- Washburn, A.L. 1988. Mima mounds: An evaluation of proposed origins with special reference to the Puget Lowlands. *Washington Div. of Geology & Earth Resources Report of Investigations* 29.
- Waters, A.C. 1933. Terraces and coulees along the Columbia River near Lake Chelan, Washington. *Bulletin of the Geological Society of America* 44: 783-820.
- Willis, B. 1887. Changes in river courses in Washington territory. *U.S. Geological Survey Bull.* 40.