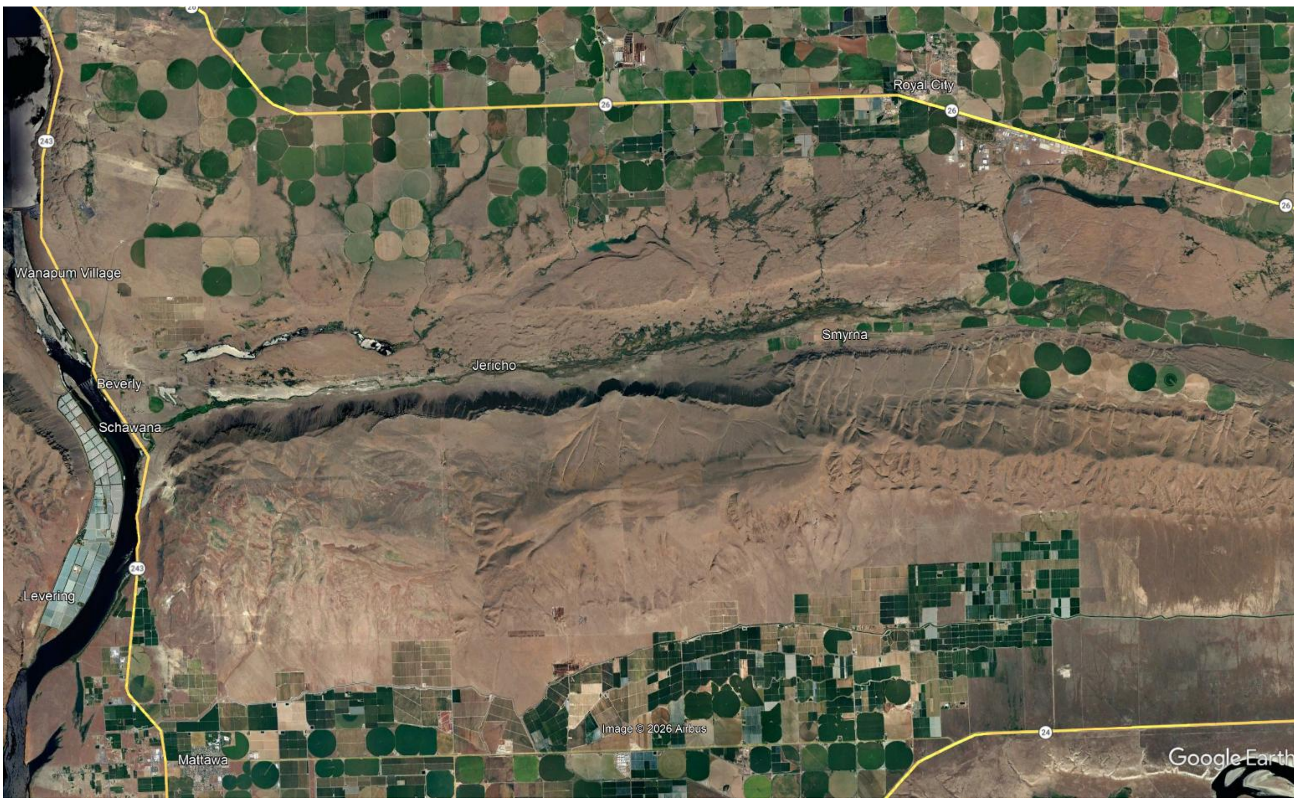
Ellensburg Chapter Ice Age Floods Institute

Lower Crab Creek Field Trip



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Field Trip Overview

Crab Creek is a perennial stream that flows over 160 miles through semiarid eastern and central Washington to join the Columbia River just south of Beverly. Lower Crab Creek lies in a broad coulee adjacent to the towering faulted and folded Saddle Mountains. Ice Age floods scoured the coulee walls. More recent rockfall and landslide deposits veneered the coulee walls, and sand dunes and salt flats blanketed the coulee floor. Native Americans have long harvested the river and shrub steppe environments of the area. In the past 130 years, the landscape has been altered by the coming of the railroad, ranching, military activity, and large-scale irrigation. Currently, the area is a mecca for outdoor-minded folks included hunters, fishers, nature lovers, cyclists, and off-road vehicle enthusiasts.

Tentative Schedule

10:00am	**Stop 1—Beverly Bar**
	Geology and geography overview; Ice Age floods
11:00	*Depart*
11:15	**Stop 2—Crab Creek Crossing**
	Crab Creek, dunes & salt flats
12:15 pm	*Depart*
12:30	**Stop 3—Smyrna Ice Cave**
	Folding, faulting, debris fans, talus & cold air drainage
1:15	*Depart*
1:30	**Stop 4—West of Smyrna**
	Landslides, scablands & public lands
2:15	*Depart*
2:30	**Stop 5—Natural Corral & Red Rock Lake**
	Ice Age floods & wild horse roundups
3:15	*Depart*

Getting to Stop 1

Stop 1 is located on the east side of the Palouse to Cascades Trail (i.e., "Beverly") Bridge over the Columbia River (Figures 1 & 2). The bridge and the Palouse to Cascades Trail forms the northern boundary of the town of Beverly. From WA 243, turn onto Lower Crab Creek Road and travel east for just under 0.2 mi. Turn left onto Seattle Street and drive north for ~0.2 mi to a trailhead just south of the Palouse to Cascade Trail. Park here or along one of the nearby streets. Make sure to pull off the streets as far as possible and don't block resident's driveways.

Our Field Stops

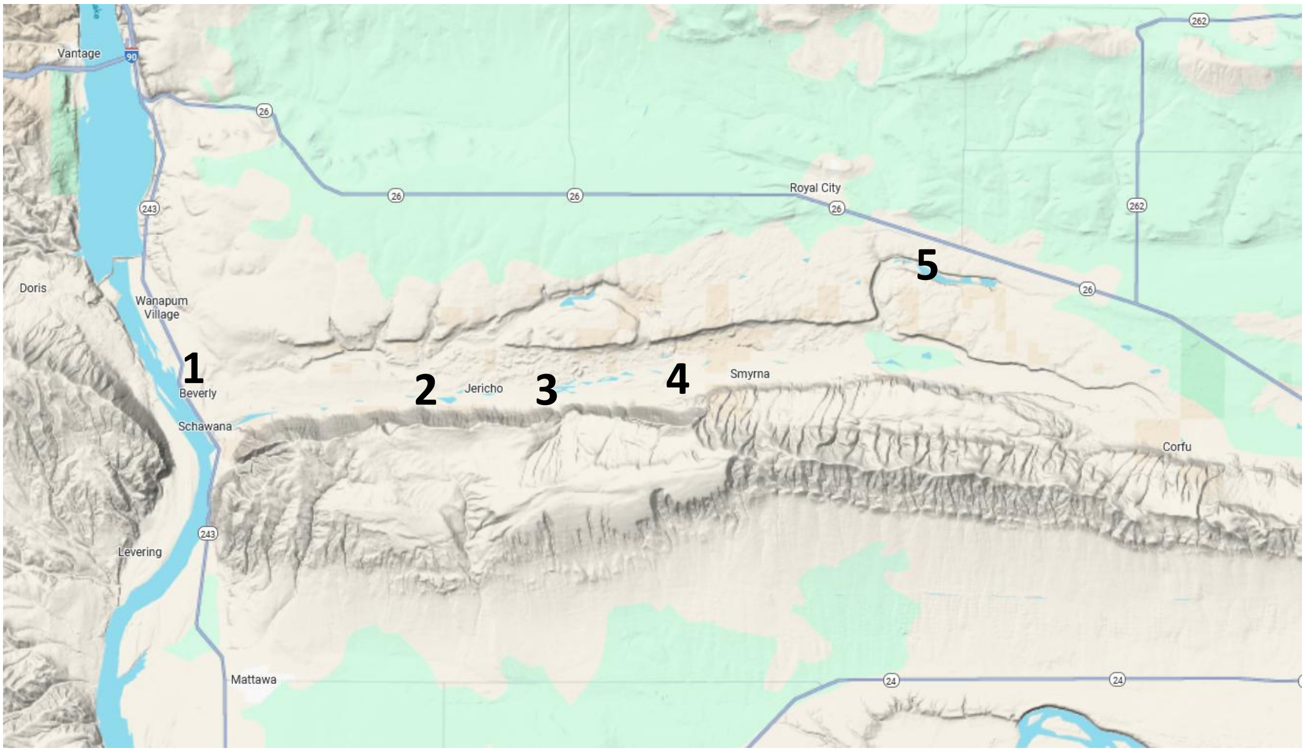

Figure 1. The approximate locations of Lower Crab Creek field trip stops noted with numbers. Source: Google Maps.

Stop 1—Beverly Bar

Location: We are located on the east abutment of the Palouse to Cascade Trail (Beverly) Bridge (Figures 1 & 2). Topographically, we are in the western portion of the Columbia Basin. The Columbia River and part of the Saddle Mountains lie west. Crab Creek and the remainder of the Saddle Mountains are south and east. Sentinel Gap is the prominent opening through which the Columbia River passes the Saddle Mountains. The low relief, rocky surface we are located on is the Beverly Bar. We are on the traditional lands of the Wanapum (i.e., "River People") that stretched from near present-day Tri Cities to this area (Schuster, 1998). Their lives were and continue to be centered on the Columbia River, especially just downstream of here in the vicinity of present-day Priest Rapids Dam.

This is an information stop. There are no restrooms here but there are pit toilets in several Washington State Fish and Wildlife parking areas enroute to Stop 2. There should also be restrooms at the gas station in nearby Schwana.

Stop 1—Beverly Bar

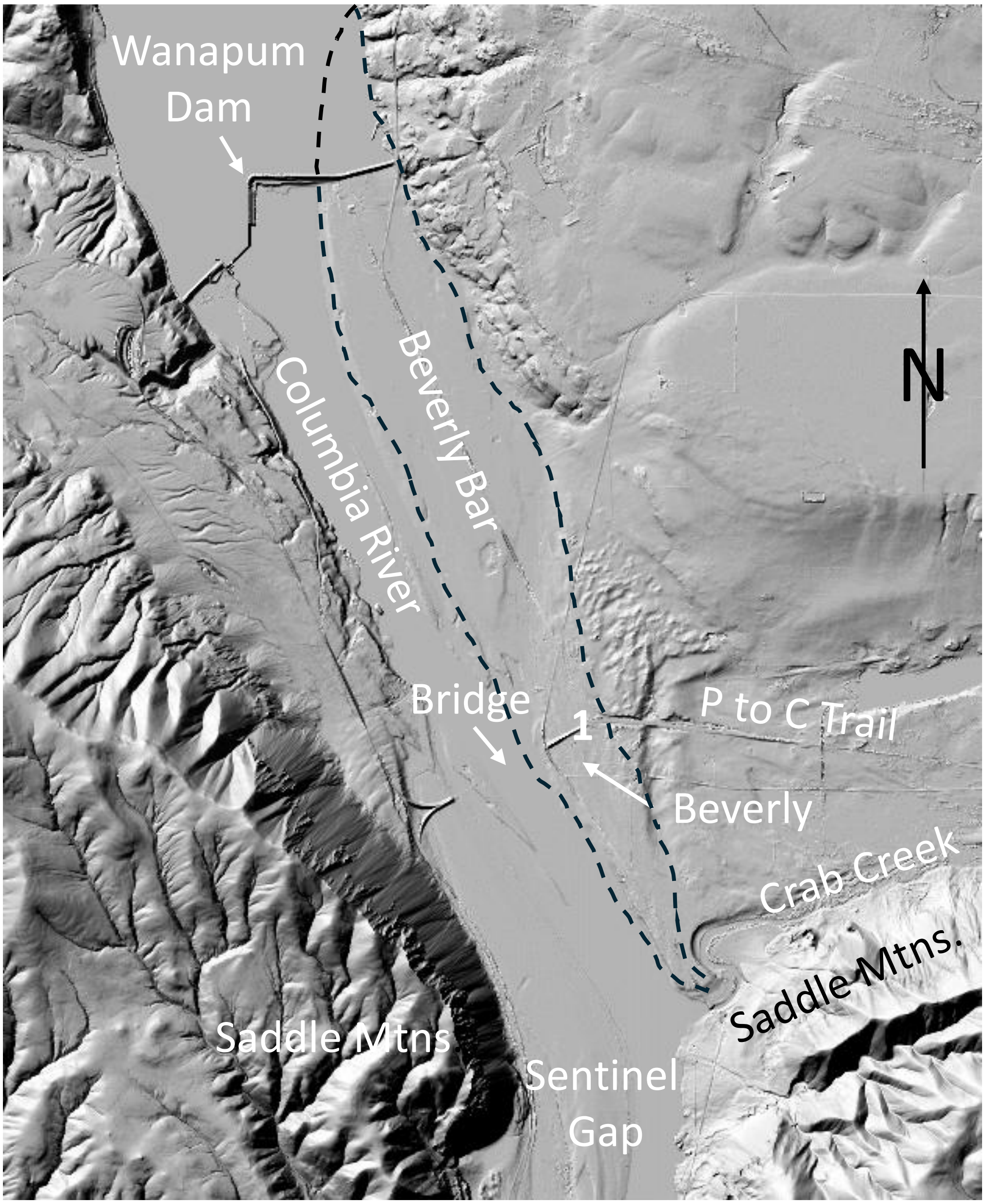

Figure 2. Lidar image of topography and places of note in the vicinity of Stop 1 (bold number). Dashed line indicates approximate extent of Beverly Bar. Source: Caltopo.com.

Stop 1—Beverly Bar

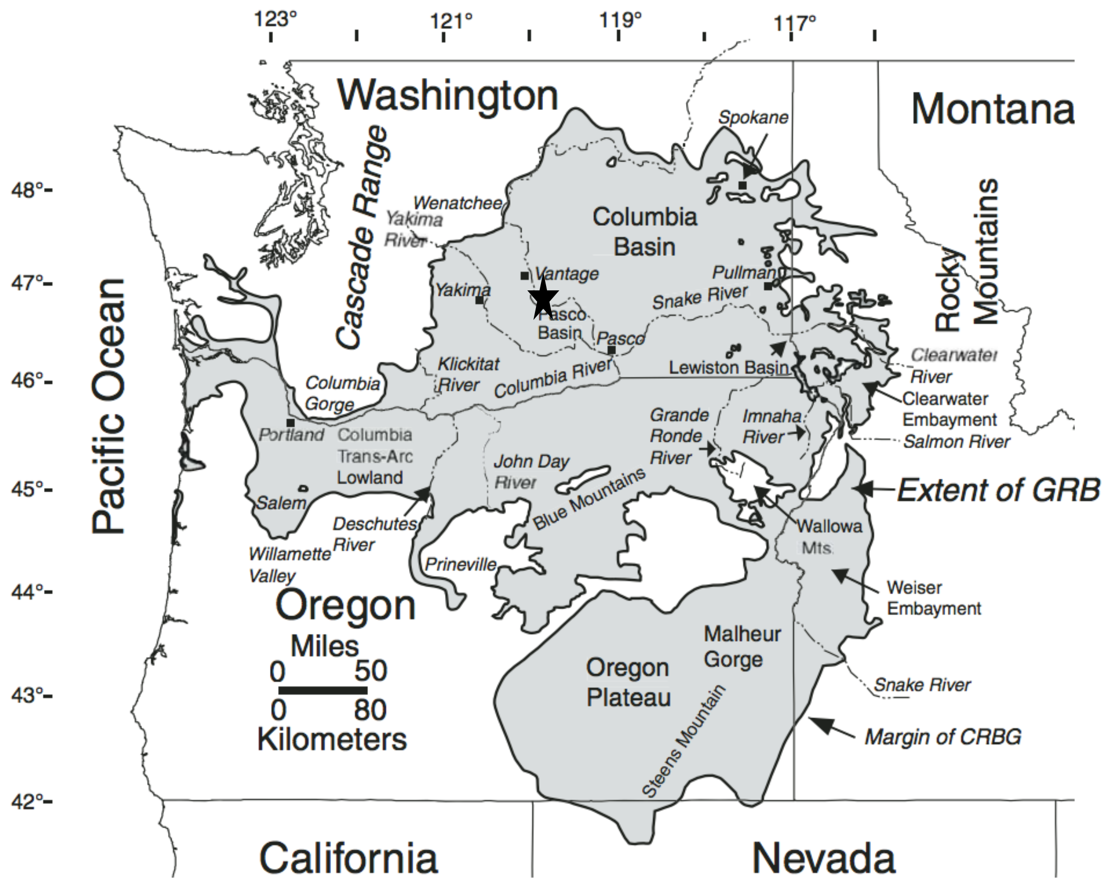

Figure 3. The extent of the Columbia River Basalt Group (dark area) in Washington, Oregon, Idaho, and northern Nevada. Star indicates approximate location of field trip area. Source: USGS Cascade Volcano Center (https://www.usgs.gov/media/images/columbia-river-basalt-group-map-shows-main-regions-basalt-exposu).

Bedrock Geology. The bedrock geology of our field day is Columbia River Basalt. These dark, dense, volcanic rocks characterize much of central and eastern Washington (Figure 3). More specifically, much of our day will be spent atop and adjacent to the Grande Ronde, Wanapum, and Saddle Mountains Basalts. Recent dating efforts suggest that the Grande Ronde and Wanapum basalts erupted over a very short period—16.6 to 15.9 million years ago (ma) (Kasbohm & others, 2023). As you can see by Figure 4, many flows compose the entire Columbia River Basalt Group. Oil and gas drilling in the Saddle Mountains revealed basalts that are over 15,000 feet thick overlying >2000 feet of sedimentary rocks (Czajkowski & others, 2012; Staisch & others, 2017). Some of these basalt flows and associated interbeds are visible in on the west side of Sentinel Gap. We will talk more about the basalts at Stop 3.

Stop 1—Beverly Bar

Series		Group	Formation	Member	Isotopic Age (m. y.)	Magnetic Polarity
Miocene	Upper	Columbia River Basalt Group	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
	Middle			**Elephant Mountain Member**	10.5	R,T
				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	N
				Basalt of Sillusi		N
				Basalt of Umatilla Member		N
			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		
			Grande Ronde Basalt	Member of Sentinel Bluffs	15.6	N_2
				Member of Slack Canyon		
				Member of Field Springs		
				Member of Winter Water		
	Lower		Grande Ronde Basalt / Prineville Basalt	Member of Umtanum		
				Member of Ortley		
				Member of Armstrong Canyon		
				Member of Meyer Ridge		R_2
				Member of Grouse Creek		
				Member of Wapshilla Ridge		
			Grande Ronde Basalt	Member of Mt. Horrible		
			Grande Ronde Basalt / Picture Gorge Basalt	Member of China Creek		N_1
				Member of Downey Gulch		
			Grande Ronde Basalt	Member of Center Creek		R_1
				Member of Rogersburg		
				Member of Teepee Butte		
				Member of Buckhorn Springs	16.5	
			Imnaha Basalt			R_1
						T
						N_0
					17.5	R_0

Nomenclature of the Columbia River Basalt Group (from Reidel and others, 2002)

Figure 4. Stratigraphy of the Columbia River Basalt Group. Recent research indicates that the lowermost Grand Ronde Basalt formed at ~16.6 mya, the Vantage interbed was deposited at ~16.1 mya, and the uppermost Wanapum (Priest Rapids member) formed at ~15.9 mya. Sources: https://www.usgs.gov/centers/oregon-water-science-center/science/columbia-river-basalt-stratigraphy-pacific-northwest#multimedia; Kasbohm & others, 2023)

Stop 1—Beverly Bar

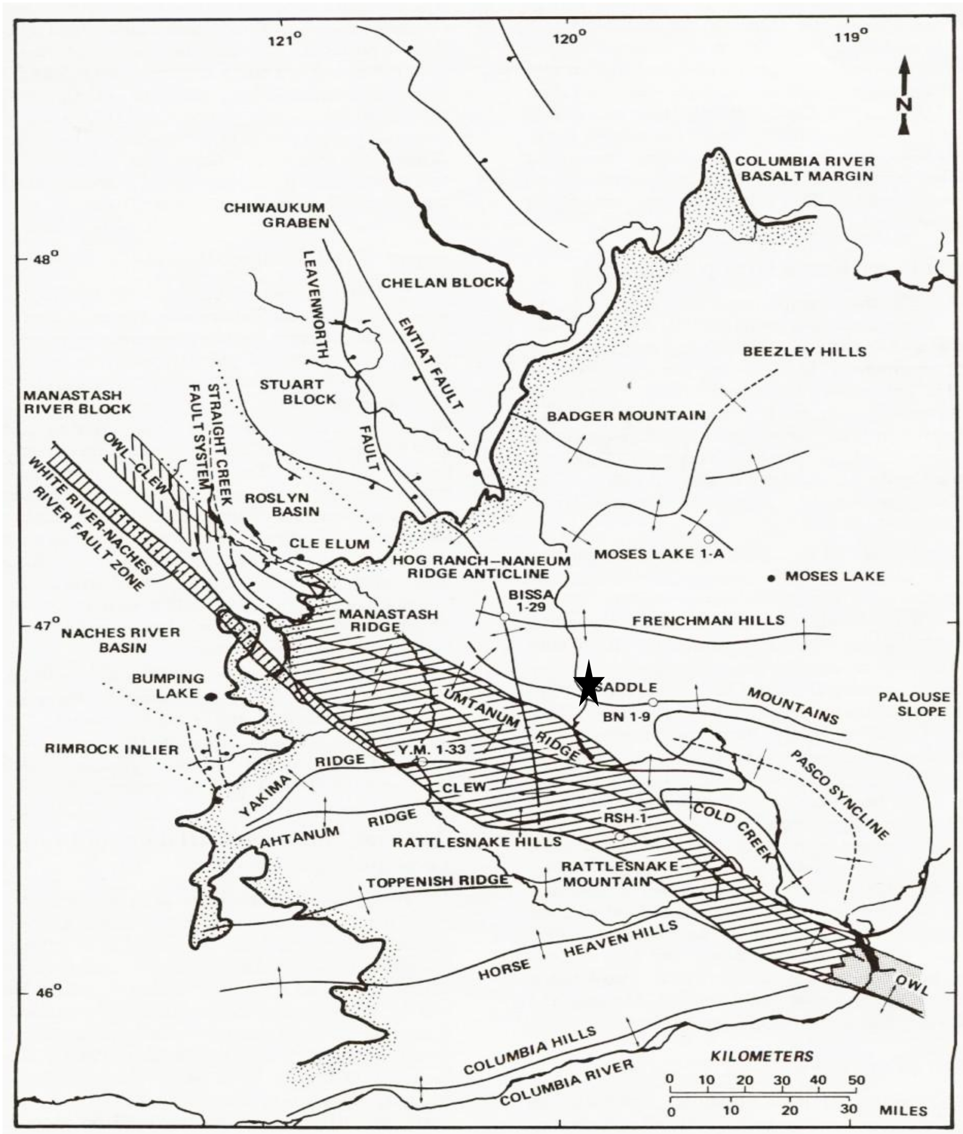

Figure 5. Generalized map of major faults and folds along the western margin of the Columbia Plateau and Yakima Fold Belt. Star indicates approximate location of field trip area. Source: Reidel & Campbell (1989, p. 281).

Structural Geology. The basalts were initially deposited horizontally or nearly so. Since deposition, they have been folded and faulted into the Saddle Mountains as part of the Yakima Fold and Thrust Belt (Figure 5). The resulting east-west trending, fault-cored Saddle Mountains anticline stretches nearly 70 miles across central Washington, east and west of here (Reidel, 1984; Staisch & others, 2017). We will discuss this further at Stop 3.

Stop 1—Beverly Bar

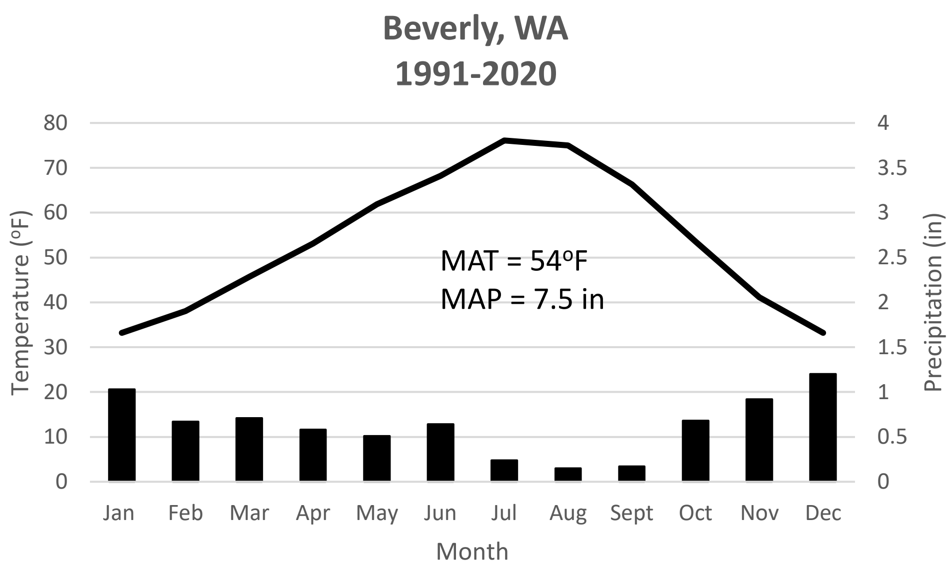

Figure 6. Modelled temperature (line graph) and precipitation (bars) for the Beverly area over the 1991-2020 period. Note the sharp contrast between winter and summer temperatures, and the low overall precipitation, especially in late summer. MAT means mean annual temperature and MAP equals mean annual precipitation. From PRISM Climate Group website (https://prism.oregonstate.edu/explorer/).

Climate. The climate of the area may be characterized as a mid-latitude, continental dryland (Figure 6). The mid-latitude and inland location means that summers are hot and winters are cold. The average annual temperature is about 54ºF, a value similar to marine-influenced Seattle and warmer than more continental Spokane. The location in the rainshadow of the Cascade Range results in overall much drier conditions (~7.5 inches 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). Winds are common and often strong throughout the year—e.g., high winds derailed railroad cars here in 1974 (Moody, 1974). When occurring in the drier months, winds are often accompanied by blowing dust. Dunefields in the area (Stop 2) indicate that winds here are primarily from the west. Given the dry and windy setting, potential evapotranspiration is likely more than 60 inches/year which is 8 times that of precipitation (Donaldson, 1979)!

Stop 1—Beverly Bar

Glacial Lake Missoula and its Floods: Ice Age floods from Glacial Lake Missoula in western Montana (Bretz, 1969) as well as from the Okanogan Valley in northcentral Washington and southcentral British Columbia (Gombiner and Lesemann, 2024) shaped this area (Figure 7).

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^3 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! At different times, these floods followed the Columbia River, flowed down the Grand Coulee, followed Crab Creek drainage, and flowed through the Palouse River drainage to the Snake River (Figure 8).

Subglacial floods associated with the Okanogan Lobe of the Cordilleran icesheet delivered floods into the westernmost scabland channel—Moses Coulee. Those floods likely only flowed down the Columbia River Valley after entering just downstream of present-day Wenatchee (Figure 8).

Most of the paths of the Glacial Lake Missoula and Okanogan Lobe floods were scoured to basalt bedrock and descriptively named the "Channeled Scablands" (Figure 7). See Bretz (1969), Baker & others (2016), Waitt & others (2021), and Gombiner and Lesemann (2024) for excellent summaries of the Ice Age flood history in the Channeled Scablands. Present-day Beverly was impacted by Ice Age floods down the mainstem Columbia River Valley and by floods passing through the lower Crab Creek Valley (Figure 8).

Stop 1—Beverly Bar

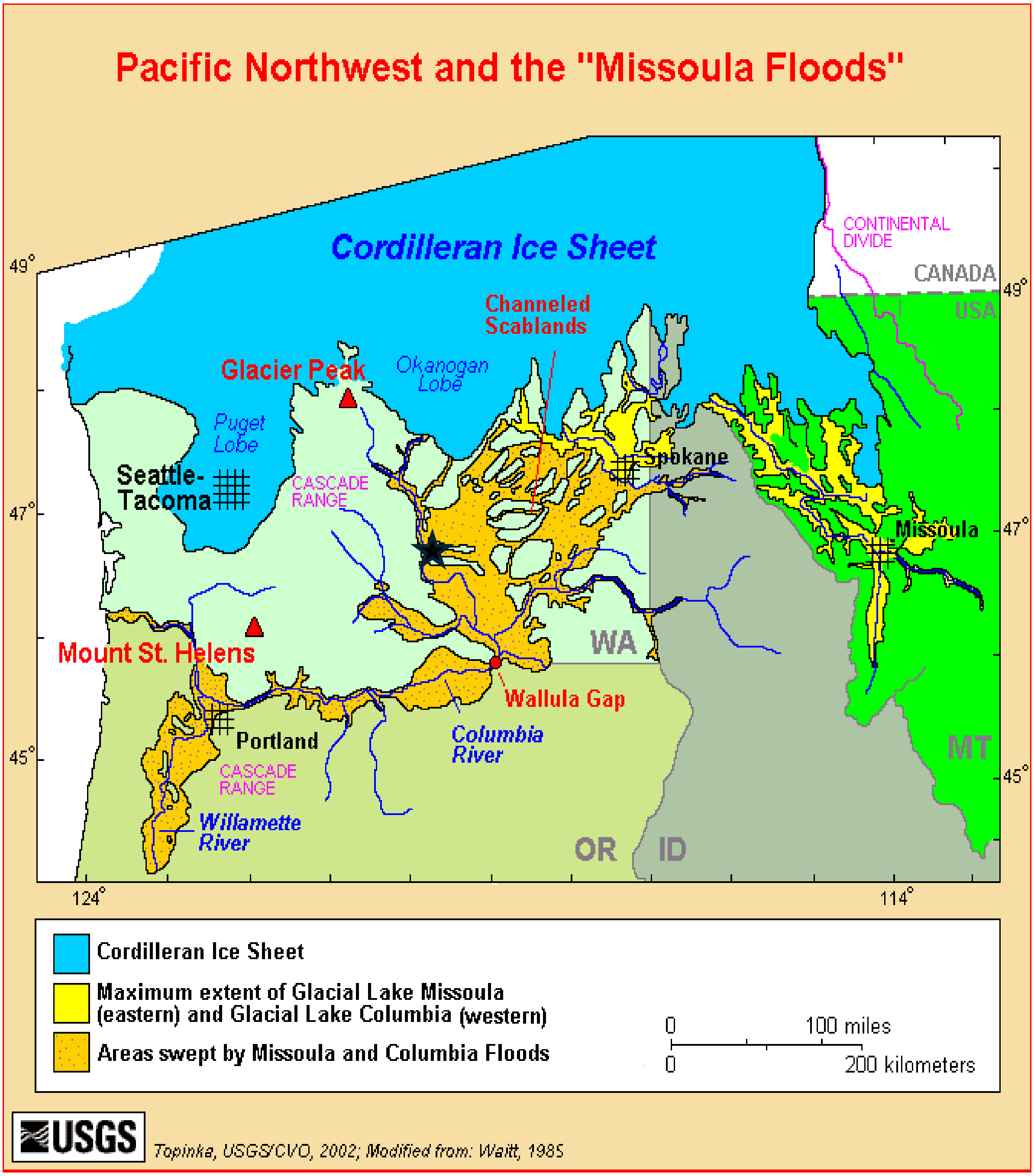

Figure 7. Map of the late Pleistocene Cordilleran Icesheet and Missoula Floods in the Pacific Northwest. Star indicates approximate location of the field trip. Source: Cascade Volcano Observatory website, https://www.usgs.gov/media/images/pacific-northwest-and-missoula-floods.

Stop 1—Beverly Bar

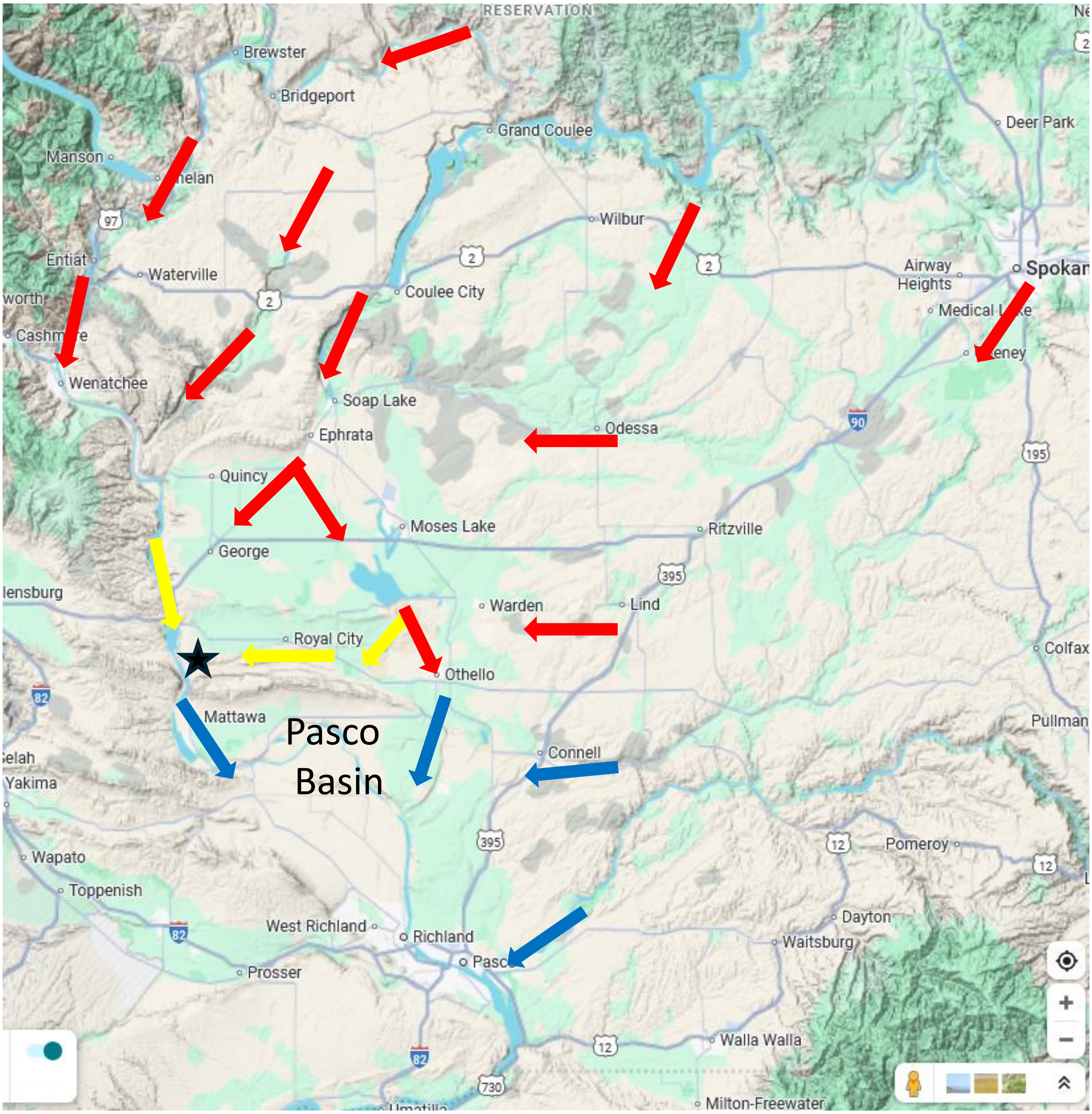

Figure 8. General flow paths of Ice Age floods north of the lower Crab Creek (red arrows), into the Lower Crab Creek (bold star) (yellow arrows), subsequently into Pasco Basin (blue arrows) areas. Sources: various + topographic maps.

Stop 1—Beverly Bar

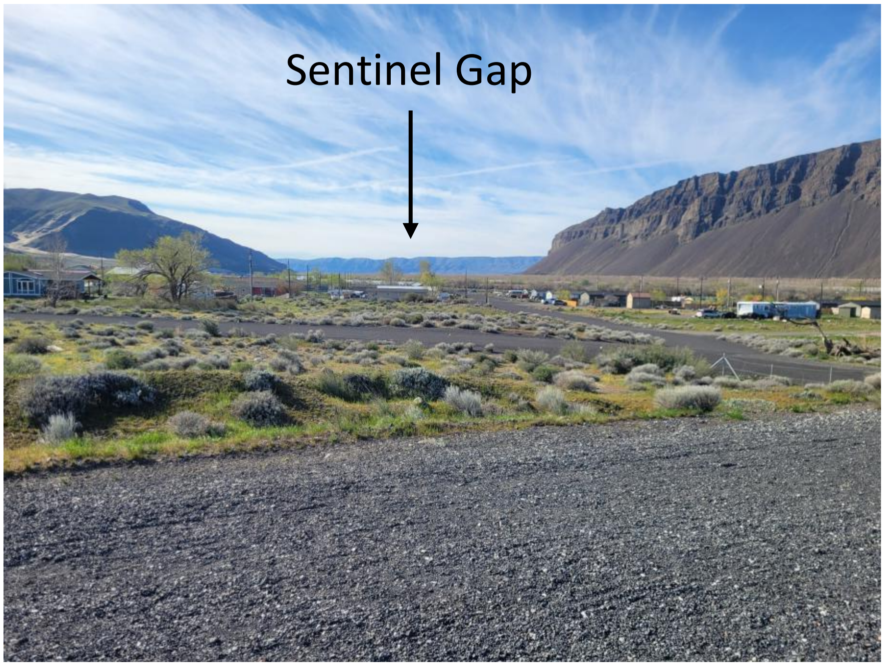

Figure 9. View south to Sentinel Gap from the east abutment of the Palouse to Cascades Trail Bridge. Note basalts exposed in west wall of Sentinel Gap. Beverly in foreground. Source: Author, 03/30/2026.

Sentinel Gap. The Columbia River flows through a water gap in the western portion of the Saddle Mountains. This gap is known as Sentinel Gap (Figure 9). The Columbia River began to erode Sentinel Gap perhaps as long ago as 13-14 million years (Bjornstad, 2006). With the rise of the Saddle Mountains over time, the Columbia incised further creating the water gap we see today. In more recent geologic time, Sentinel Gap was the westernmost of four main routes for Ice Age floodwaters to enter the Pasco Basin (Bjornstad, 2006) (Figure 8). This channel was likely widened and deepened further by Ice Age floods.

South and west flowing Ice Age floods encountering Sentinel Gap were likely only impounded a short time before passing through or backing up sufficiently to flow around the east end of Saddle Mountains (Bjornstad, 2006). However, waters from the Pasco Basin did back up into this area. Because the flow into the Pasco Basin was greater than the channel out of the basin (i.e., Wallula Gap), water backed up to form Lake Lewis. This lake backed up through the ~500 foot elevation of Sentinel Gap up to over 1260 feet elevation, leaving iceberg-rafted erratics (Karlson, 2006) in the Ginkgo Petrified Forest State Park. I have also seen erratics at approximately that elevation west of Doris along the Palouse to Cascade Trail. Such lakes, presumably associated with each major flood, would have put us under nearly 700 feet of water at various times in the late Pleistocene!

Stop 1—Beverly Bar

Longitudinal Bar. We are standing on a longitudinal bar formed by an Ice Age flood that travelled down the mainstem Columbia River Valley (Figure 2). Longitudinal bars form on margins of rivers and are usually measured in feet. This longitudinal bar is at least five miles long and initially blocked the mouth of Crab Creek where it entered the Columbia River. The presence of this bar on the floodplain indicates that it was deposited late in the Ice Age flood sequence or it would have been eroded away by later floods (Bjornstad, 2006). Based on elevation on the floodplain, Bjornstad suggests that this bar was likely deposited by the same flood as that which deposited the giant current ripples at West Bar ~30 miles upstream near Trinidad.
Milwaukee Railroad. We are standing on the abandoned railbed of the Chicago, Milwaukee & St. Paul Railroad (often called the Milwaukee Railroad or Milwaukee Road). The Milwaukee Railroad extended from the upper Midwest to Tacoma (Wood & Wood, 1972). Construction occurred here in the early 1900's and led to the creation of Beverly (Figure 10). Freight service began through this area in 1909 followed by passenger service in 1911 (Ward, 2013). Beverly station sat just east of here in the prominent cut through the longitudinal bar (Figure 11). The Milwaukee Road struggled financially over its history. High costs of western expansion (e.g., the Milwaukee was not a land grant railroad), federal control of railroads during World War I, the economic depression of 1929, worker strikes, and competition with other railroads and with increased highway traffic all played a role in its demise (Ward, 2013). Passenger service ended in 1961 (Wood & Wood, 1972) followed by freight in 1980 (Ward, 2013). In 1981, the state of Washington purchased the rail corridor. Over time, it became the John Wayne Trail/Ironhorse State Park. It has all since been renamed the Palouse to Cascades State Park Trail.
Hydropower. Two dams, both owned and operated by Grant County Public Utility District, operate in this stretch of the river. Just downstream of here, Priest Rapids Dam began generating electricity in 1959 (https://www.grantpud.org/history). This dam resulted in Priest Rapids Lake that stretches upstream to the present-day site of Wanapum Dam (which lies just over 3 miles upstream of here). Just upstream lies Wanapum Dam which went online in 1963. Its completion resulted in Wanapum Lake that stretches approximately 30 miles north nearly to Rock Island Dam (https://www.grantpud.org/history). These dams greatly changed the nature of this portion of the Columbia River, especially for the Wanapums who have long depended on riverine resources. Of particular interest to this field trip are the impacts of the submerged Columbia River floodplain on downwind dunefields. We will discuss these issues at Stop 2.

Stop 1—Beverly Bar

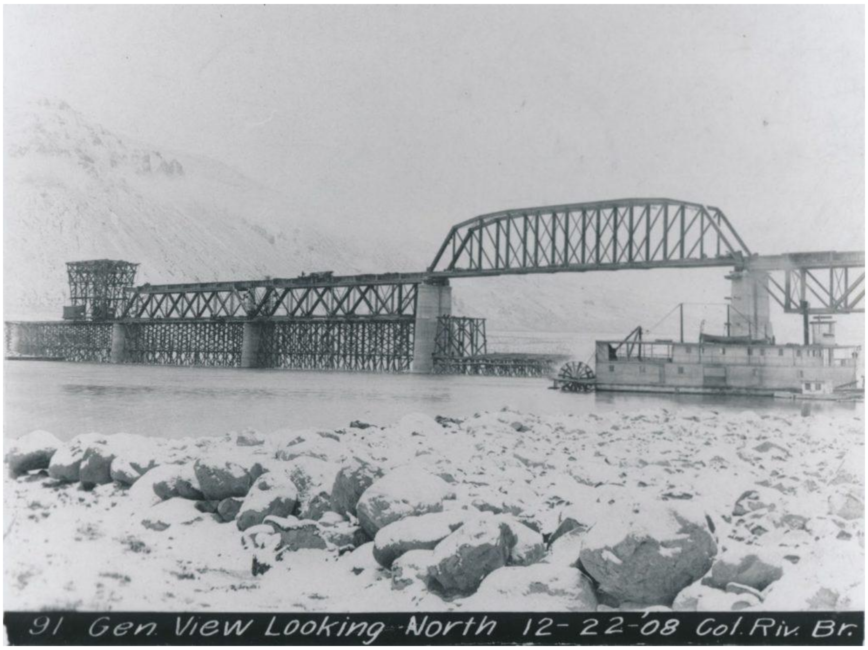

Figure 10. Beverly Bridge under construction in December 1908. Note the sternwheeler St. Paul that hauled men, fuel, and material (including steel for construction of bridge) from the Vulcan Great Northern station near Wenatchee downriver to Beverly. Source: Borleske (2020) and Othello Community Museum.

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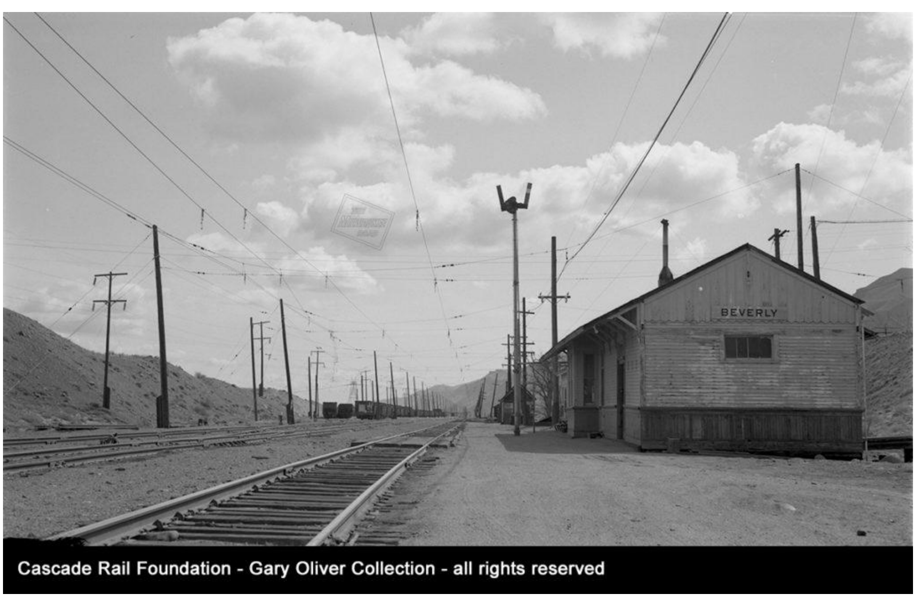


Figure 11. View eastward along Milwaukee Railroad toward Beverly depot and Saddle Mountains, April 1976. Beverly Bridge behind the photographer. Photographer: likely Stan Styles. Source: Borleske (2020).

Enroute to Stop 2

From Stop 1, return to Lower Crab Creek Road (Figure 12). Turn left (east) and follow Lower Crab Creek Road ~5.4 miles. We will park along the road about 0.7 miles past the Lake Lenice Public Access site and just downstream of the bridge over Crab Creek. From there we will walk south and west several hundred yards to an area of dunes and salt flats. This is Stop 2.

This drive will take us past a large dunefield on the right (south) and sand veneered scablands to the left (north). Lush (by central Washington standards) vegetation along the road results from a high water table associated with Crab Creek and with irrigation runoff. The public access sites along the road are primarily associated with irrigation runoff-formed fishing lakes—e.g., Nunnaly and Lenice. Each of these sites as well as the sand dunes recreation site has vault toilets.

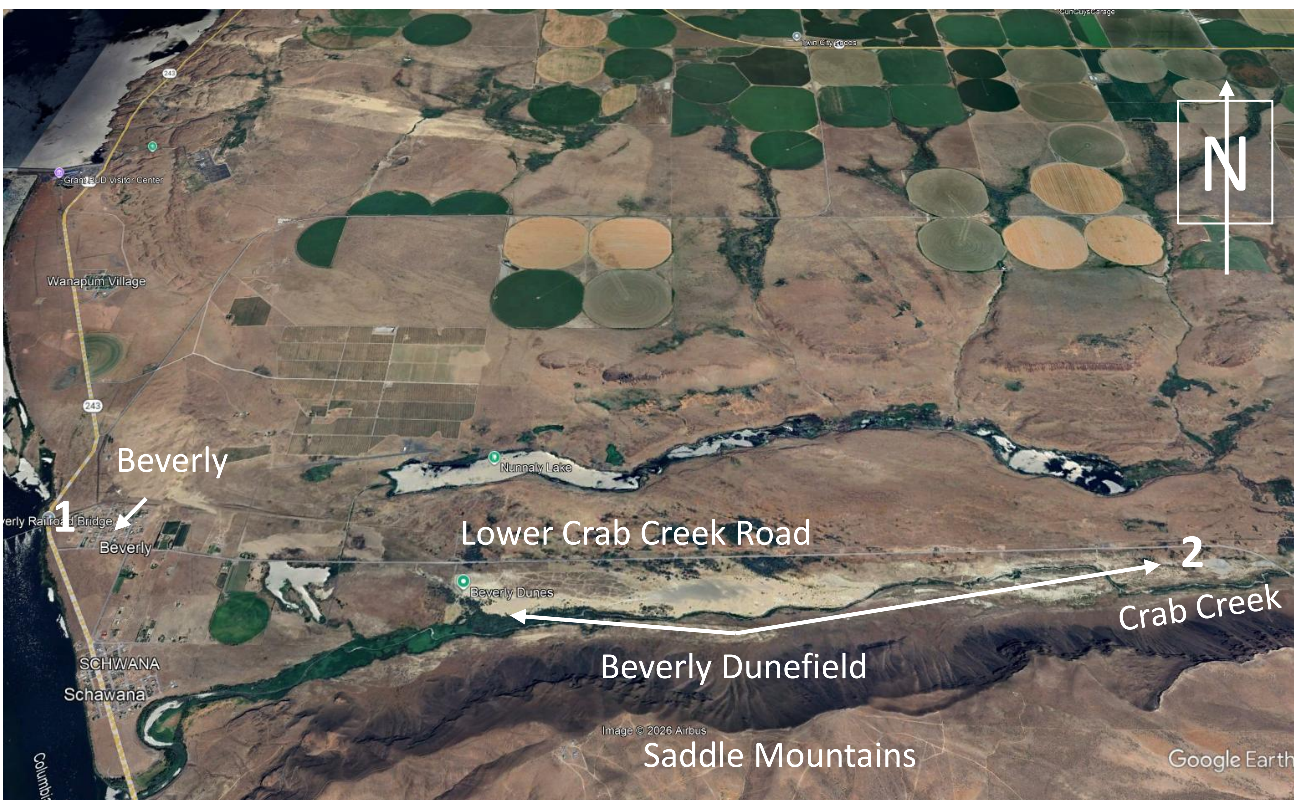


Figure 12. Oblique aerial view of Stops 1 and 2 (bold numbers). Light colored areas along Crab Creek are sand dunes and small salt flats (i.e., playas). Source: Google Earth Pro.

Stop 2—Crab Creek Crossing

Figure 13. Very approximate path of Crab Creek (dashed line) from its origin near Edwall to the Columbia River. Source: various topographic maps http://www.waterplanet.ws/crabcreek/ccrhome/map.html.

Location. We will have several mini-stops at this stop. All are within several hundred yards of Lower Crab Creek Road. The first will be along Crab Creek at 46.831370°N & 119.818839°W. From here, we will walk to the top of a nearby sand dune (46.831653° & 119.819861°W) followed by a walk to the edge of a playa (46.831917°N & 119.818691°W).

Crab Creek. Crab Creek is one of just a handful of natural (i.e., non-irrigation created), perennial streams in the central part of Washington. It starts near Edwall (~25 miles southwest of Spokane) and flows about 160 miles to join the Columbia River just south of Beverly (Figure 13). Enroute, it loses flow to local irrigation withdrawals in the upper part of the drainage basin and subsequently picks up surplus flows from the Columbia Basin Irrigation Project in the lower portion of the basin. It flows through natural Moses Lake and human-created Potholes Reservoir. I suspect the Wanapums and other Native Americans depended on this stream for fish and other resources. Among those other resources were likely beaver that I expect were trapped out by early trappers.

Stop 2—Crab Creek Crossing

Sand dunes. Sand dunes may not immediately come to mind when thinking of central and Eastern Washington. However, dunes are more common here than you might think (Figure 14). Everything necessary for their formation has traditionally been here—i.e., ample sand, a semiarid climate to dry the sands, and frequent, strong winds to help mobilize the dry sand. Dune forms vary with sediment source, wind direction, vegetation cover, depth of groundwater, and human activity (Figure 15). They may be active (i.e., moving), stable (i.e., immobile and vegetated) or a mix of both.

Beverly Dunes. The Beverly Dunes consist of a mix of stable and active dunes stretching from near the mouth of Crab Creek to here (Figure 12). The dunefield is present on both sides of Crab Creek and is mostly on the valley floor. These dunes are predominantly parabolic in shape (Figures 15 & 16) reflecting the unidirectional winds paralleling the Saddle Mountains and the relatively high water table (associated with Crab Creek)in the area. Unidirectional winds also help result in the overall elongate nature of the dunefield. The high water table supports sand stabilizing vegetation. The active portion of the dunefield is kept active by offroad vehicle (ORV) use—i.e.. little vegetation grows in this area because of ORV use; therefore, there is little root strength to hold sand in place.

Beverly Dunes Over Time. Like most inland sand dunes in Washington state, the Beverly Dunes originated on the downwind (typically east) side of the Columbia River (Figure 17). They likely began to form soon after the passage of Ice Age floods through the area. Floodplains are great sediment sources for dunes, and when combined with the pervasive winds of the area, resulted in extensive dunefields. The Columbia River floodplain (including the Ice Age Flood-deposited Beverly Bar) was the sediment source here (Figures 2 & 17). Once set in motion, sands migrated downwind by bouncing and rolling away from their sediment sources to form the elongate Beverly dunes. Therefore, the sands here likely migrated at least 5.5 miles from the Columbia River. The sediment source of this dunefield were mostly cutoff when the Columbia River floodplain was submerged by the lakes behind Priest Rapids and Wanapum dams in the late 1950's and early 1960's. Elsewhere in the Columbia Basin, irrigated agriculture has stabilized active dunes since the 1950's.

Stop 2—Crab Creek Crossing

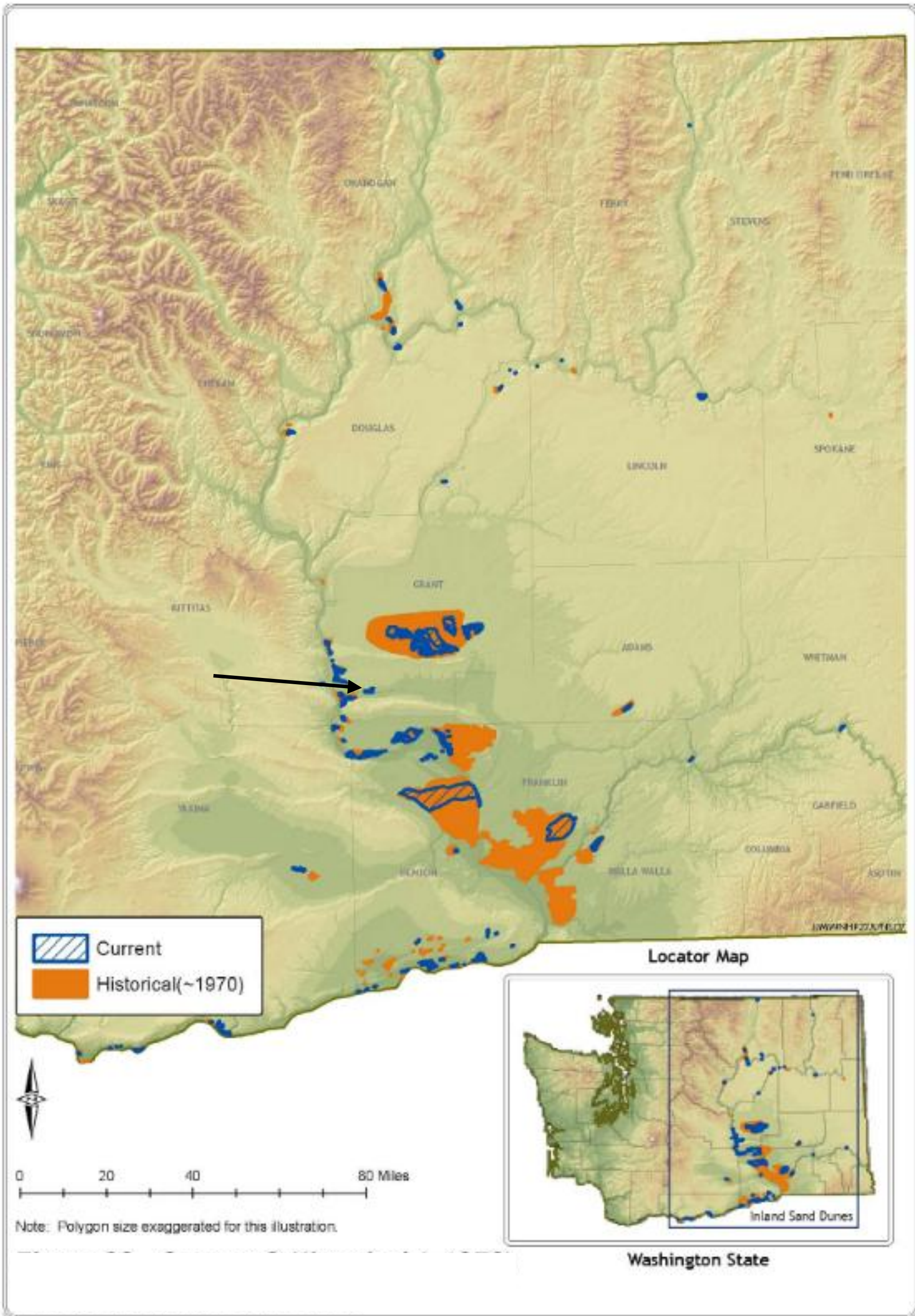


Figure 14. Current and historical (~1970) extent of inland sand dunes in Washington state. Tip of arrow indicates approximate location of Stop 2. Source: Hallock & others (2007).

Stop 2—Crab Creek Crossing

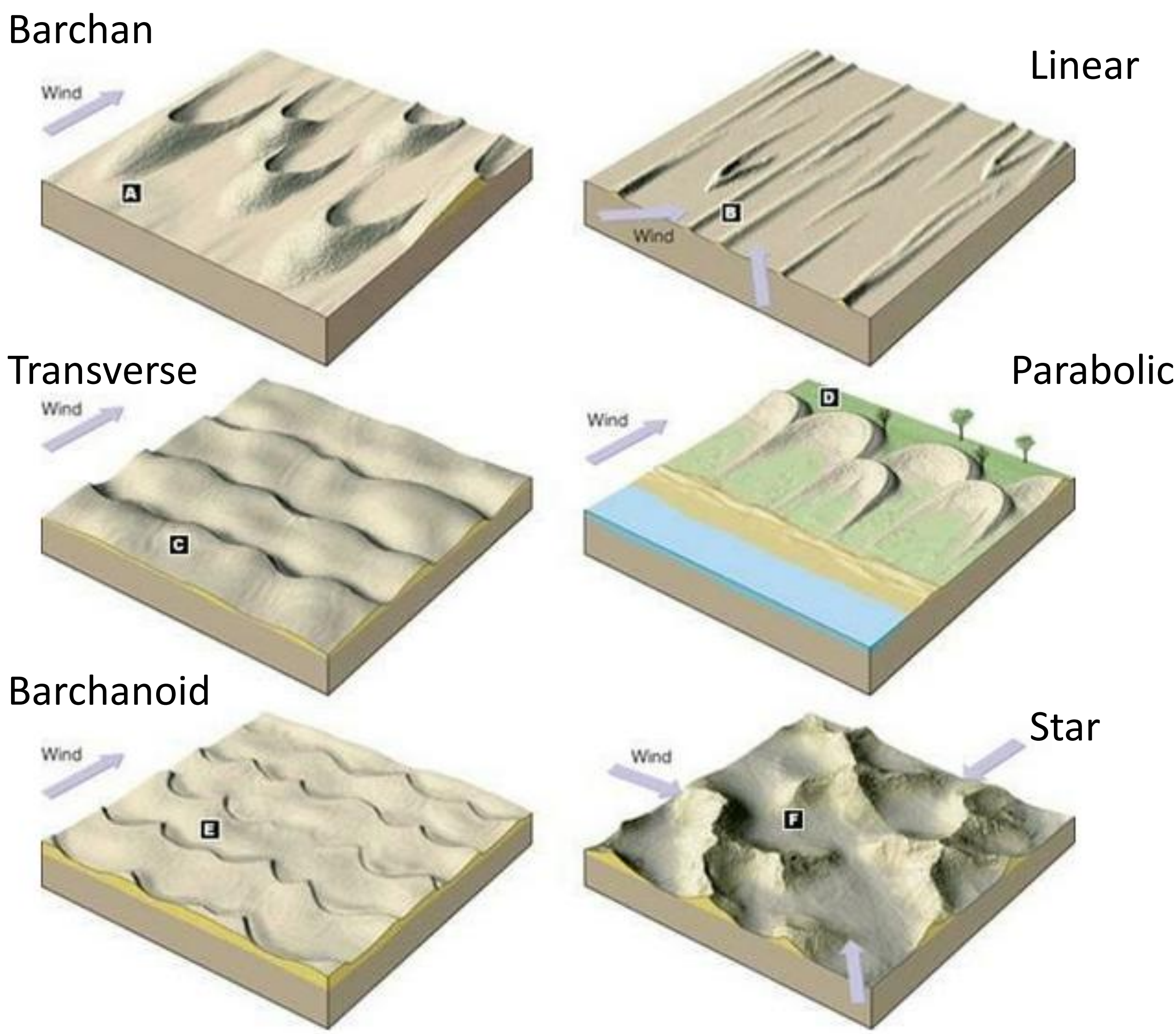


Figure 15. Basic dune types. Adapted from McKee (1979) by Al-Zubaydi (2023, p. 1160)

Stop 2—Crab Creek Crossing

Figure 16. Vertical image of mostly stable parabolic dunes (red line) and playas at Stop 2. Wind direction show with bold arrow. Source: Google Earth Pro, 7/25/2023.

Dunes & Mount St. Helens Ash. Look carefully in the dunes here for remnants of Mount St. Helens ash. It occurs as a gray-white layer, often about 0.5 inches thick (Figure 18). Here, where relatively undisturbed, it occurs beneath a foot or more of sand. This sand likely came from the area now occupied by the playa to the west (Figures 16 & 19). This suggests that significant sand movement has occurred in the past 46 years. If exposed over a large area, the topography of ash can often tell us about dune migration since May 1980.

Figure 18. May 18, 1980 Mount St. Helens ash (arrowed) in a ~stable portion of the Beverly dunefield. Source: Author photo, 03/30/2026.

Stop 2—Crab Creek Crossing

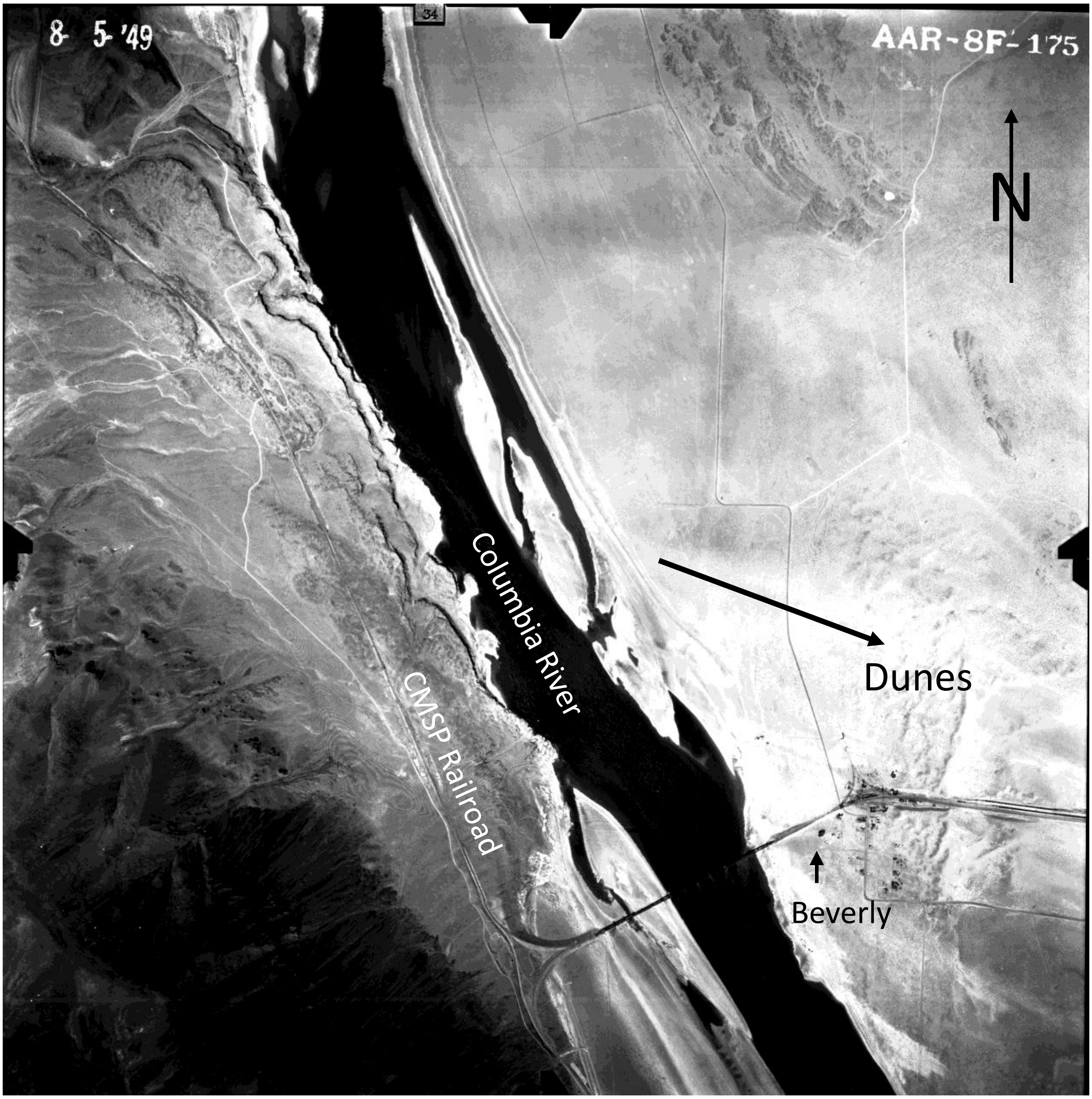


Figure 17. Vertical aerial view of sand sources for dunes in the vicinity of Beverly in 1949. Sand sources indicated by light toned, irregularly shaped surfaces on Columbia River floodplain. Note the preponderance of dunes east of the Columbia River floodplain. Bold arrow indicates approximate sand movement direction. Source: Central Washington Historical Aerial Photograph Project, Kittitas County AAR-8F-175, August 5, 1949.

Stop 2—Crab Creek Crossing

Figure 19. Stop 2 playa and parabolic dune downwind of playa. Source: Author photo, 03/30/2026

Playas. Flat, white areas lacking vegetation cover and surface outlets are common on the floor of lower Crab Creek Valley. These playas form when surface- and groundwater-fed, small, seasonal ponds and wetlands evaporate leaving behind salts that were previously dissolved in the waters of this semiarid setting. The saltgrass (*Distichlus stricta*) and greasewood (*Sarcobatus vermiculatus*) vegetation of the areas adjacent to the playas reflects the saline soils here. When wet, playa floors may be soft and sticky…not a good place to walk or ride! When dry, playa salt surfaces often crack, forming polygons that looking quite similar to the tops of basalt columns. These cracked salt polygons are susceptible to erosive removal by wind (i.e., "deflation"). Salts may help deflation by limiting vegetation growth and causing typically cohesive clays to disaggregate into pellets. The groundwater table limits the depth to which wind will deflate playa floors (Laity, 2008).

Playas and Dunes. In many places, playas have been overtopped by sand dunes that have migrated over this valley floor for centuries. In other places, dunes form the eastern margins of playas. These dunes may be made of sand or clay pellets that formed with desiccation of valley floor, and winds picking up the dry, fine textured sediments and moving them by saltation (i.e., bouncing) to the margins of the playa. There they accumulate as dunes. The dune on which we were standing is one such feature.

Enroute to Stop 3

From Stop 2, we will continue east on Lower Crab Creek Road for ~3.3 miles to a playa on the right (south) side of road. A large boulder with "14" painted on it is located on the playa. Park along the east side of the road. GPS coordinates: 46.830874°N & 119.748766°W.

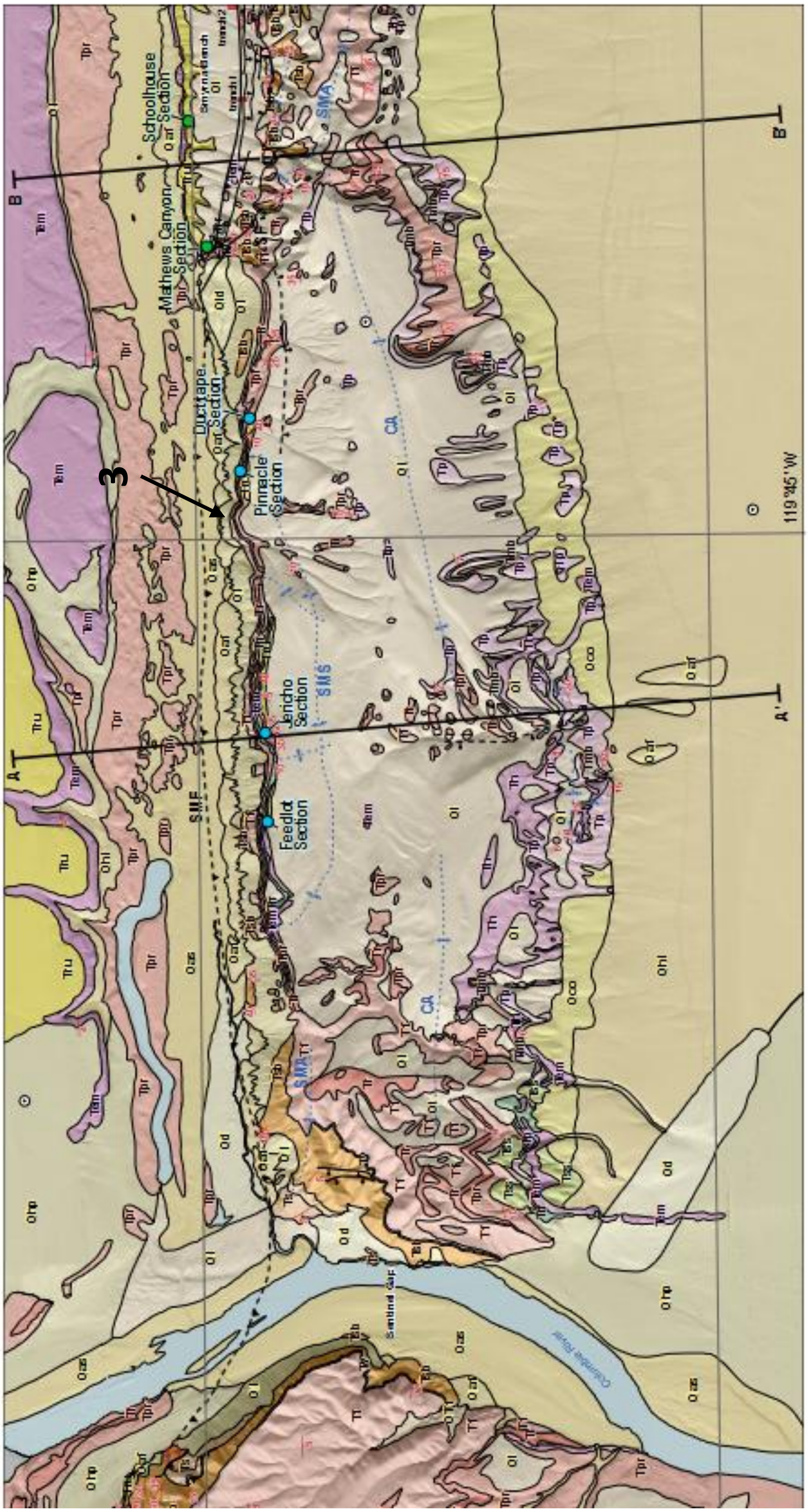
Stop 3—Smyrna Ice Cave

Location. From our parking spot we will walk across or around the west end of the playa (depending on how wet the playa is) to the talus at the base of the steep mountain front.

Folding & Faulting. We are located at the steep base of the east-west trending Saddle Mountains. This is a fault-cored anticline that extends nearly 70 miles from near Othello to east of Ellensburg (Reidel, 1984). The anticline is generally asymmetrical in cross section resulting in a steep north face and gentler south face. The presence of the Saddle Mountains fault, a south dipping reverse fault, very near where we are standing, helped create this tall, linear north face (Staisch & others, 2017) (Figures 20 & 21). The stresses required for the folding and faulting were directed north-south. Ice Age floods likely over steepened this slope as well.

Previous studies show that deformation in the area began prior to the deposition of the Columbia River Basalts and has continued to historic times (see various sources in Staisch & others, 2017). It appears that deformation increased after ~10 Ma and continued until ~3.5 Ma, and this deformation was significant. For example, ~75 to 940 feet of structural relief was generated on various parts of the Saddle Mountains anticline over the ~10-6.8 Ma period (Staisch & others, 2017). Illustrating this, there is about 900 feet of topographic relief (i.e., coulee floor to top of Saddle Mountain)! Slip rates on the fault have have been estimated at ~0.006-0.009 inches/year since about 6.8 Ma (Staisch & others, 2017). Based on these numbers, 2,000 to 11,000 years would be required to accumulate sufficient strain to develop a large magnitude (M>7) earthquake. This suggests that this fault zone poses a hazard to nearby hydroelectric dams, Hanford nuclear facilities, and communities (Staisch & others, 2017).

Stop 3—Smyrna Ice Cave



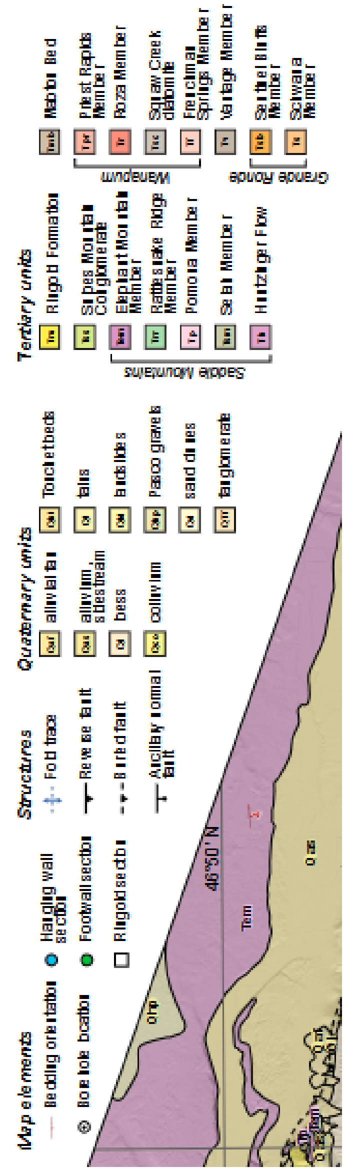


Figure 20. Geologic map of a portion of the Saddle Mountains. Bold 3 indicates approximate location of Stop 3. Source: Staisch & others 92017)

Stop 3—Smyrna Ice Cave

Colluvial Fans & Talus. The north face of Saddle Mountains is an ideal place to form alluvial fans and talus. It is very steep, tall, and composed of well-jointed basalts. This results in debris flows that formed during infrequent high precipitation or snowmelt events. Such flows follow canyons down to the coulee floor. As the debris leaves the confines of the canyon, it spreads out to form fan-shaped features—i.e., alluvial fans (Figures 21 & 22). Talus forms from rockfall high on the slopes. The falling rock concentrates into narrow canyons and accumulates as talus cones at the base of the steep mountain front. Over time, these cones may coalesce with other talus cones to form near-continuous talus aprons, or they may coalesce with alluvial fans to form more complex aprons. Such is the case here. The net result of talus cones, alluvial fans, and landslides is an undulatory mountain front (Figure 22).

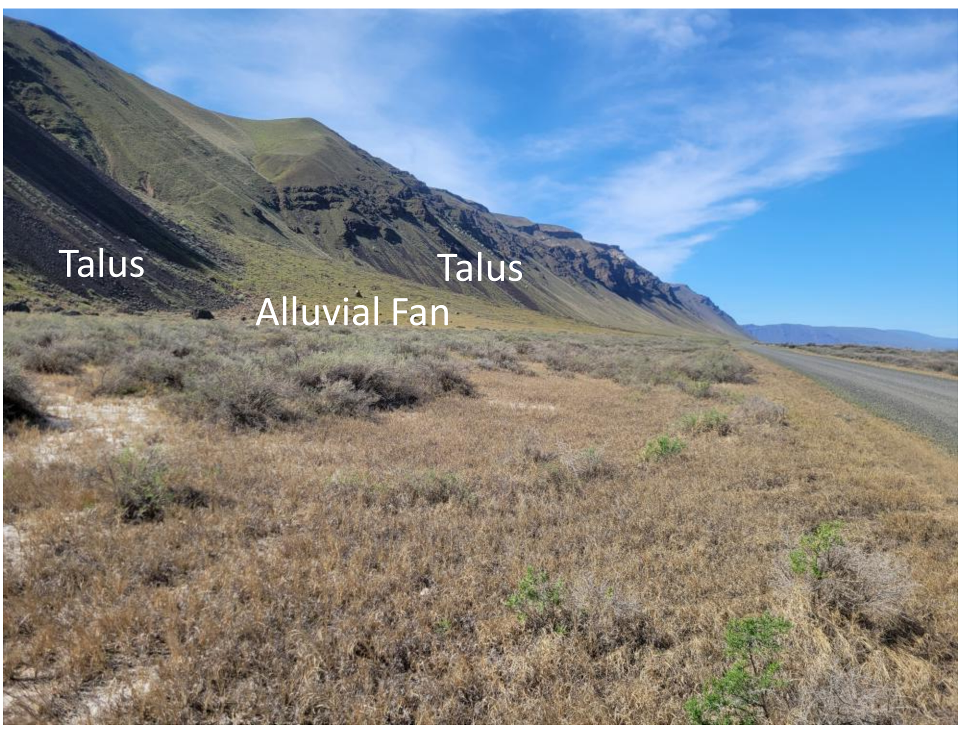


Figure 21. Abrupt north face of Saddle Mountains. Looking west from near Smyrna Ice Cave. Source: Author photo, 03/30/2026.

Stop 3—Smyrna Ice Cave

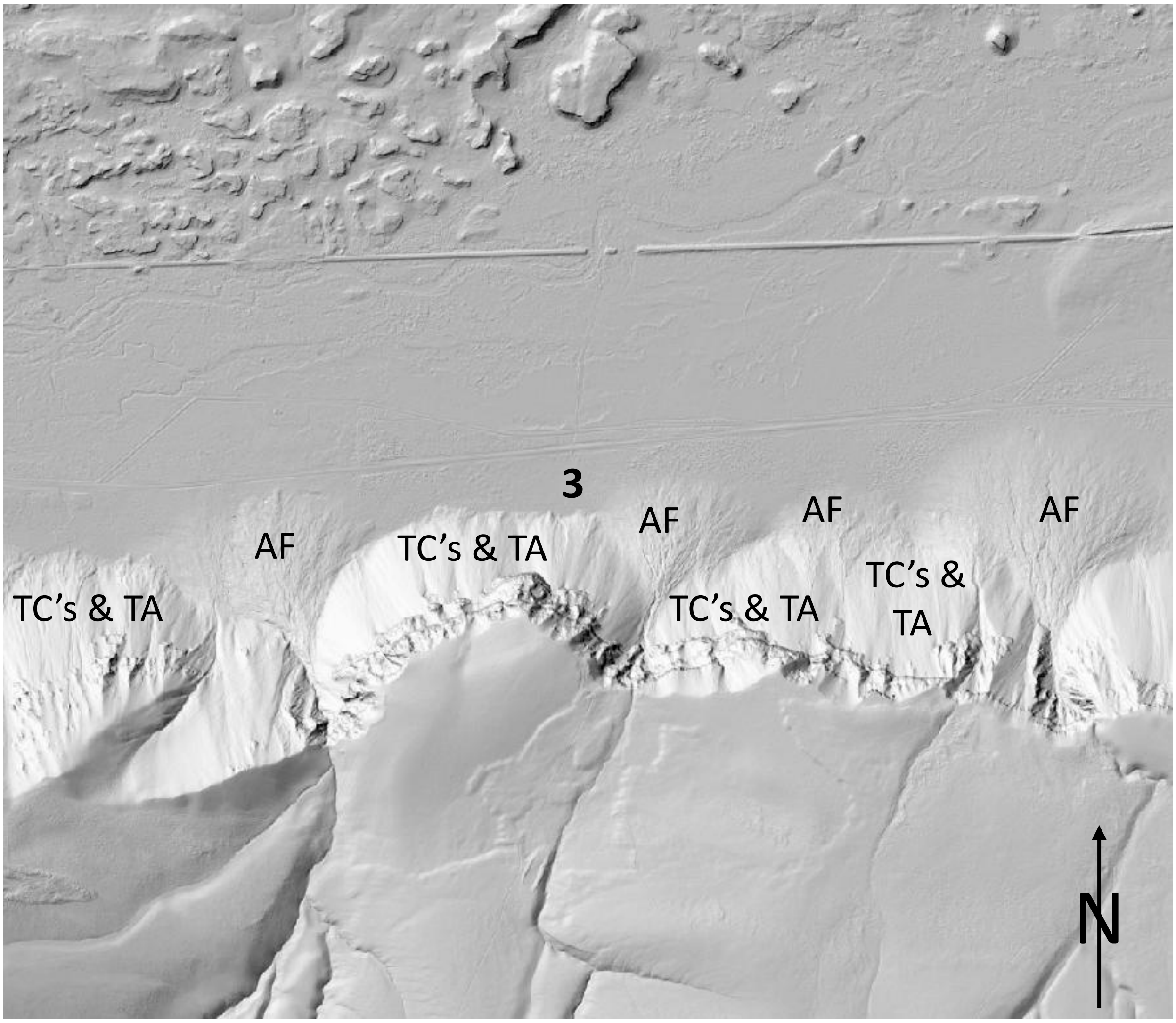


Figure 22. Lidar image of Stop 3 and vicinity. Note the different appearance and position of alluvial fans (AF) versus talus cones (TC) and talus aprons (TA). Bold number 3 indicates field stop location. Source: Washington Lidar Portal.

Smyrna Ice Cave. Shallow caves (or "rockshelters") are common in portions of the Columbia River Basalts eroded by Ice Age floods. They are typically found on coulee walls above talus accumulations. The Smyrna Ice Cave was different. It was located at the base of a large talus accumulation on the north face of Saddle Mountains. Laborers on the nearby Milwaukee Railroad in 1906-09, after seeing ice formed on the ground there long after surrounding snow and ice was gone, excavated about 10 feet back into the talus in an attempt to create a natural refrigerator for storing food in the hot summers (Eshleman, 1975). No doubt, they also felt the cold air flowing out of the rocks here that many have

Stop 3—Smyrna Ice Cave

Smyrna Ice Cave (continued): reported since. At the same time, they shored up the opening, added a door, and roofed the excavation. By the 1930's local farmers and ranchers used the "ice cave" to store meat and other perishable items (Eshleman, 1975). This "ice cave" reportedly even became a place of summer picnics (complete with ice cream made from ice cave ice). Sadly, with the advent of electricity and refrigeration in rural areas, the ice cave fell into disrepair due to continued rockfall at the base of the talus. By the 1970's it had mostly collapsed (Figure 23). All that is left now is what appears to be the top beam of the former opening (Figure 24).

So why did such a feature form? Many theories have been thrown about including the burial of a part of a glacier (Eshleman, 1975). The most logical is "Balch ventilation" (Thompson, 1962; Humlum, 1997). Talus is a permeable medium that also acts as an excellent insulator because of the air voids between rocks. Under calm conditions and scant snow cover in winter, cold air will infiltrate talus. As it cools, it becomes more dense and descends. When water seeps into talus in the wetter winter months some will typically freeze. Some of the resulting ice will remain through the year because of the insulating nature of the overlying talus and dead air spaces. Such cold places are relatively common throughout the region and include taluses in the Grand Coulee (Amara and Neff, 1996) and rock glaciers (Lillquist and Weidenaar, 2021) in the Cascade Range.

Stop 3—Smyrna Ice Cave

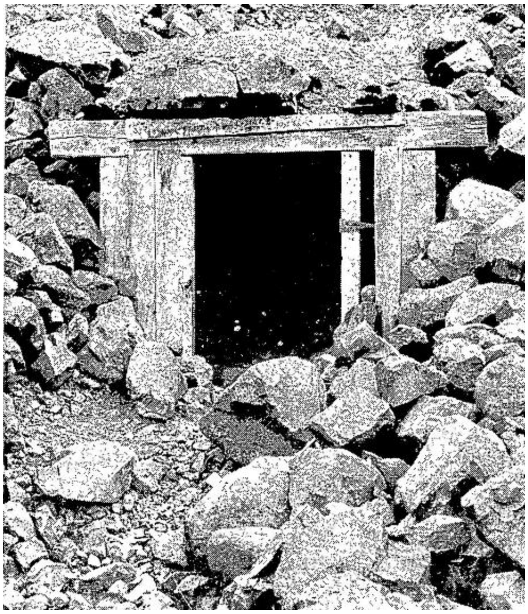


Figure 23. Smyrna ice cave entrance as of 1975. Source: Eshleman (1975, p. 1).

Figure 24. Smyrna ice cave entrance(?) (white arrow) as of 2026. Source: Author, 03/30/2026.

Enroute to Stop 4

From Stop 3, continue east on Lower Crab Creek Road for ~2.5 miles. At a sharp bend in the road, a small gravel road takes off to the left (west). You can follow the gravel road for several hundred yards to a small parking area or park on the main gravel road and walk to the parking area.

Stop 4—West of Smyrna

Location. From the parking area, walk up 10 yards or so onto the Palouse to Cascade Trail. *GPS coordinates of parking area: 46.838294°N & 119.702239°W.*

Landslides. From the previous stop, you know that the steep northern front of the Saddle Mountains has been susceptible to rock fall and debris flows over geologic time. We refer to such gravity driven movements as "mass wasting". Besides falls and flows, other types of mass wasting include slides and spreads (Figure 25). The view south from here reveals two prominent landslides (Figure 26) (Grolier & Bingham, 1971). What is the evidence for these features? The hummocky terrain of the lower portion each slide really catches my eye. The steep escarpment above the hummocky terrain is also a key line of evidence. It was the area of origin for each of the slides. Why do landslides form in basalts? Basalt flows are often separated by sedimentary layers such as those seen at Stop 1. Such layers serve as weak surfaces on which the wasting occurs. Moisture is often associated with landslides, and that may seem odd here near the driest part of the state. Based on the subdued nature of hummocky terrain, I suspect these features are old—i.e., late Pleistocene. This area may have been wetter then than at present. Groundwater may also play a key role in lubricating the weak layer. Given that Ice Age floodwaters rushed through this coulee, undercutting may also played a role here.

To see a much larger area of mass wasting, we could drive ~10 miles east of here to the area around Corfu. There, much of the north face of Saddle Mountains is characterized by mass wasting, with some of the features extending well out from the mountain front onto the coulee floor (Figure 27). The so-called Corfu landslide is a compound-complex feature consisting of 24 separate mass wasting events that include slides, spreads, and flows in bedrock and debris (Lewis, 1985). It extends across nearly 4 miles of the north face of Saddle Mountains. Over time, the mass wasting events likely retreated headwardly (like headward recession associated with Ice Age floods) to near the crest of Saddle Mountains. These events were likely caused by the weak sedimentary interbeds, geologic bedding dipping down to the north, and beds weakened by faulting, Ice Age flood undercutting and/or earthquakes may have triggered these features. Based on morphology of the features and ages of volcanic ashes, the landslides appear to have occurred between about 13,000 and 7000 yr BP (Lewis, 1985).

Stop 4—West of Smyrna

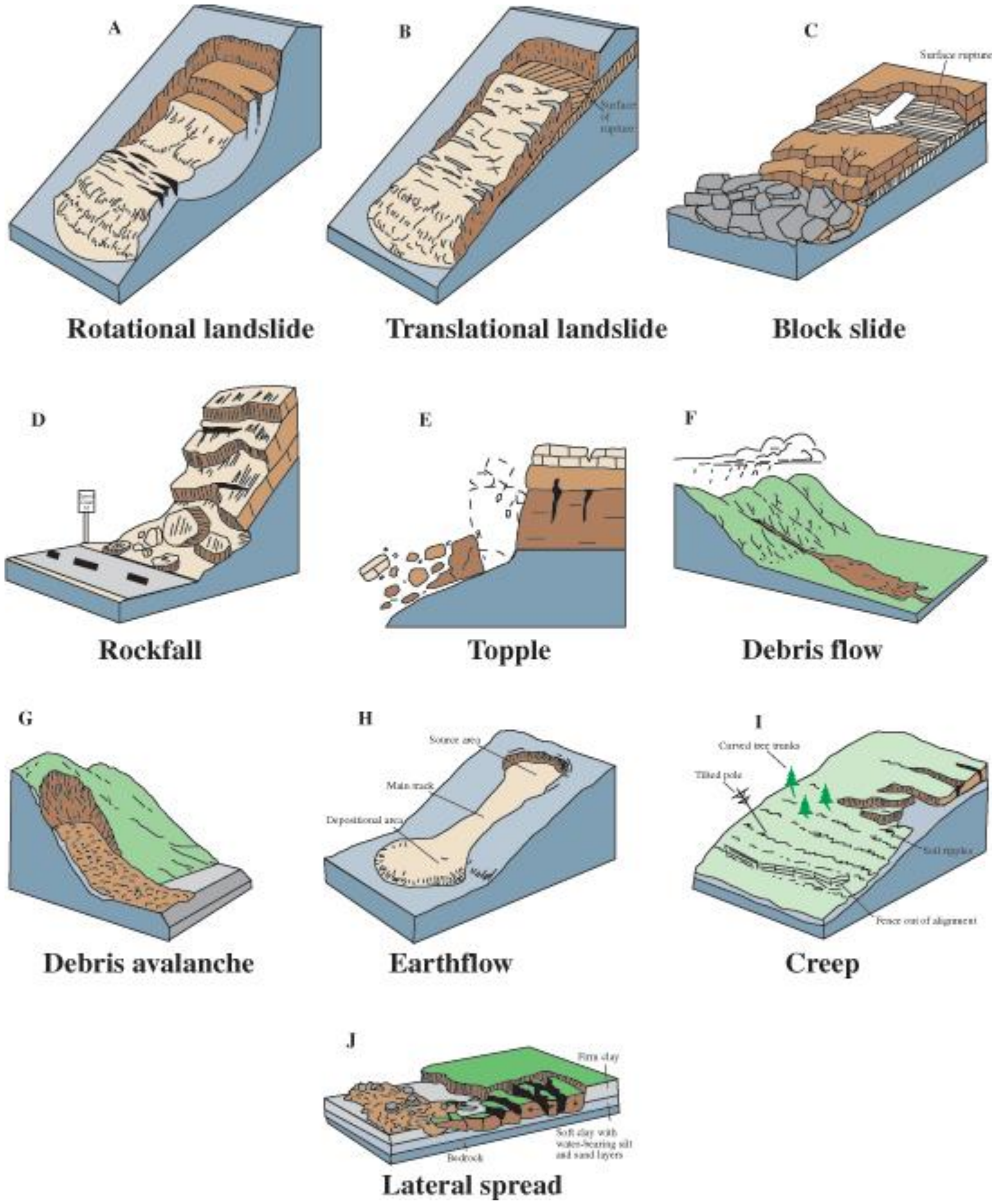


Figure 25. Different types of mass wasting. Source: https://pubs.usgs.gov/fs/2004/3072/pdf/fs2004-3072.pdf

Stop 4—West of Smyrna

Figure 26. Landslides (white outlines) on north face of Saddle Mountains visible from Stop 4. Arrows indicate approximate direction of movement. Source: Author photo, 03/30/2026.

Stop 4—West of Smyrna

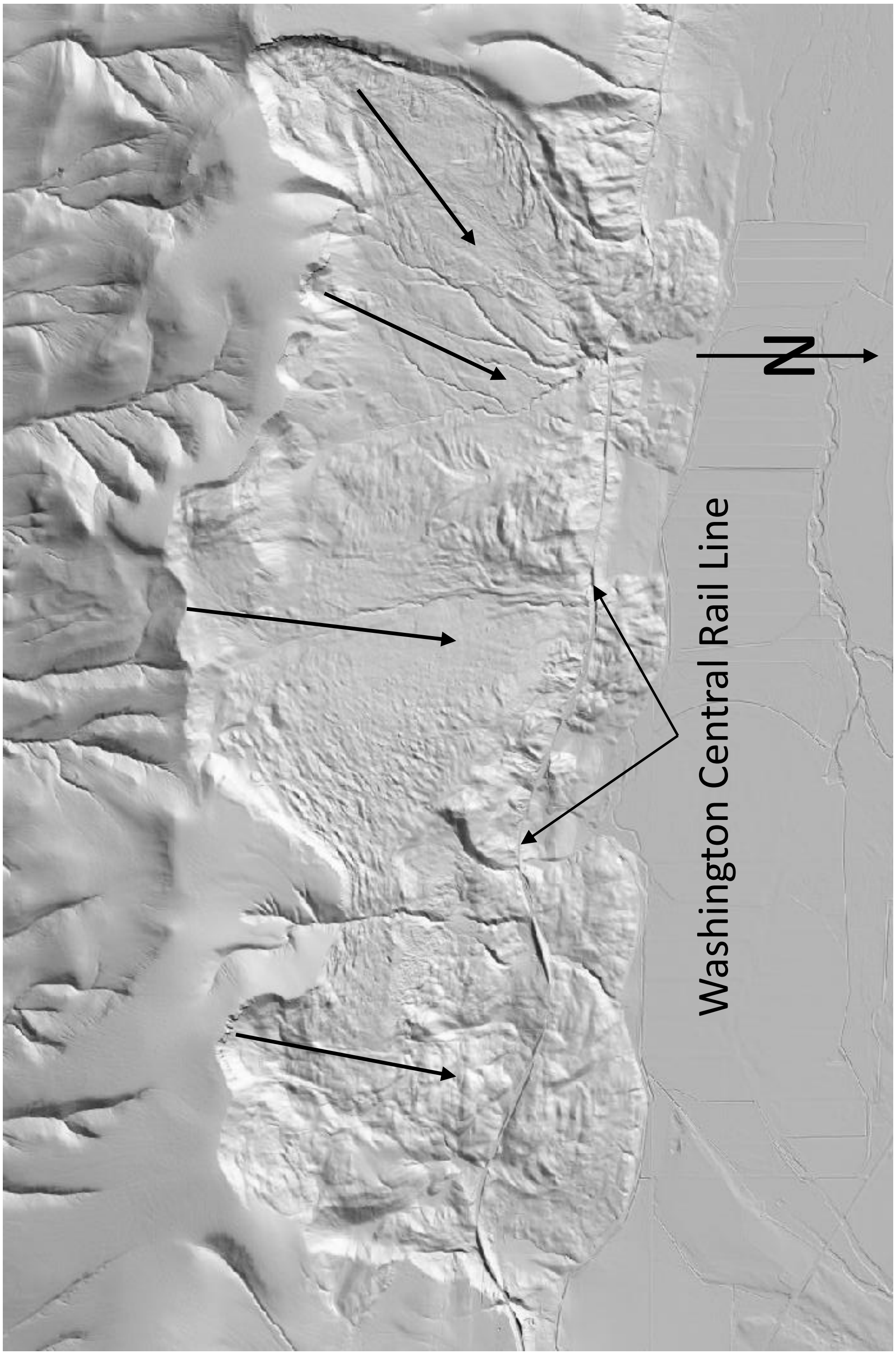


Figure 27. Lidar image of Corfu landslide. Arrows indicate general direction of movement into Crab Creek Coulee. Source: Washington Lidar Portal.

Stop 4—West of Smyrna

Scablands. We have field tripped through an Ice Age flood-impacted landscape all day but have not focused on floods since Stop 1. Since Stop 1, we have been paralleling scablands on the north side of Crab Creek Coulee. Why are the scablands there and not on the south side of the coulee? I think they were here after the floods but before the ample mass wasting. Mass wasting here in the form of falls, flows, and slides have largely covered these scabland surfaces. And moving downstream, the dunes that parallel the Saddle Mountain front cover many scablands.

Jericho Coulee to the northwest of here is an Ice Age flood channel eroded through the Ringold Formation (a sedimentary unit post-dating the basalts) into Columbia River Basalts. Dry Island is a mesa that is a remnant of a once contiguous surface. The coulee shows two directions of flow (Figure 28). The southernmost channels (white arrows) are hanging coulees (HC) suggesting that they formed in earlier floods after which the northernmost channel and the main channel flowed and eroded downward (Bjornstad, 2006).

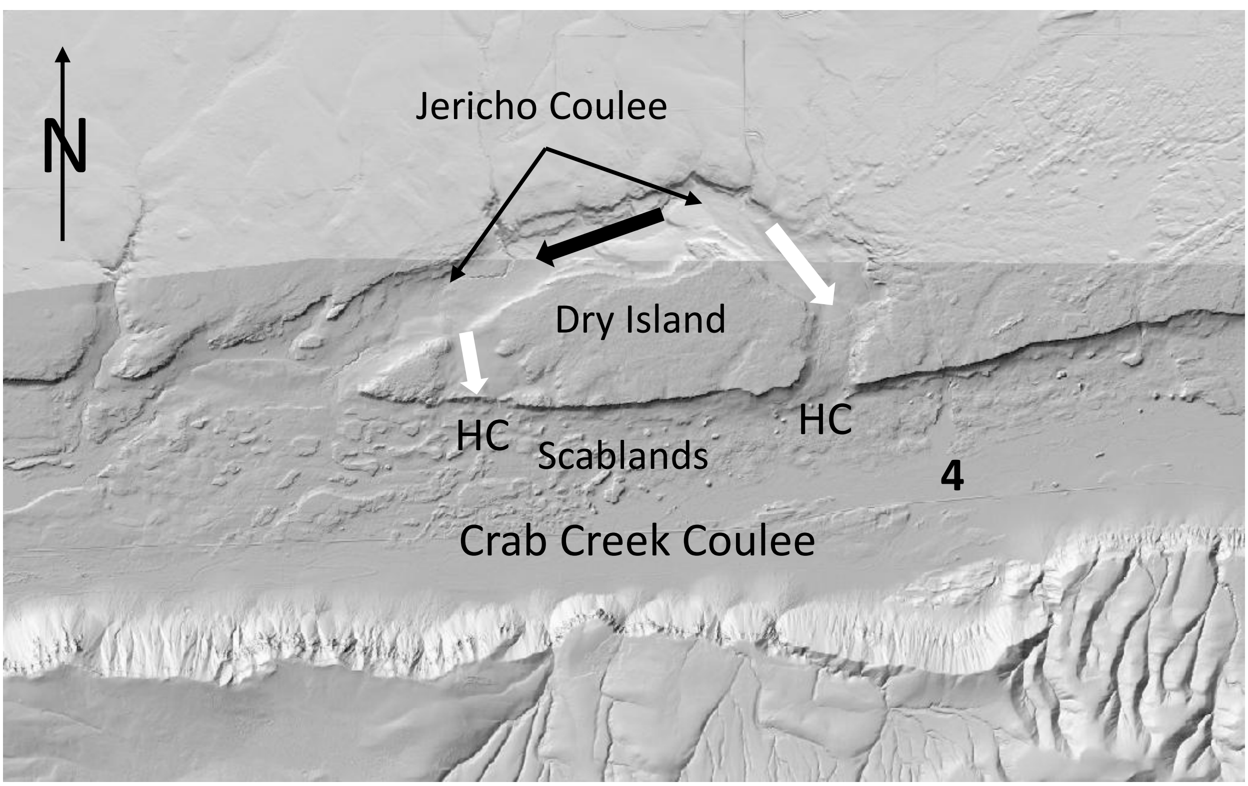


Figure 28. Scablands north of Stop 4. Note the odd channel shape of Jericho Coulee. Bold number indicates approximate location of Stop 4. Source: Washington Lidar Portal.

Stop 4--West of Smyrna

Scablands as Public Lands & Military Lands. Figure 29 shows land ownership in the lower Crab Creek area. Note that much of the land along our route is colored purple, peach or yellow. These are public lands while private lands are white. The predominance of public land here is largely a product of Ice Age flooding that eroded soil cover leaving behind scablands. Scablands had much less value to homesteaders than areas with deeper soils when the area was being settled in the late 1800's and early 1900's. Consequently, most of these lands were not taken up under the various federal government land allotment programs until the Columbia Basin Irrigation Project came along in the early 1950's. And most of that irrigation occurred north of here on the Royal Slope. An exception to this the irrigated farming Immediately east of here. I suspect that soils are deeper there because of alluvial fan deposits. This area also sits above the Crab Creek floodplain where high water tables and subsequent salt accumulation are not likely issues.

Public lands in drylands are also commonly used for military training. This is the case in central Washington where the Yakima Training Center covers 327,000 acres (511 mi^2) west and southwest of Stop 1! During World War II, bombing and strafing ranges were scattered about Central Washington. I know of at least four targets on the Waterville Plateau and four near here. We are within ~4 miles of the nearest bombing target. Can you see it on Figure 30?

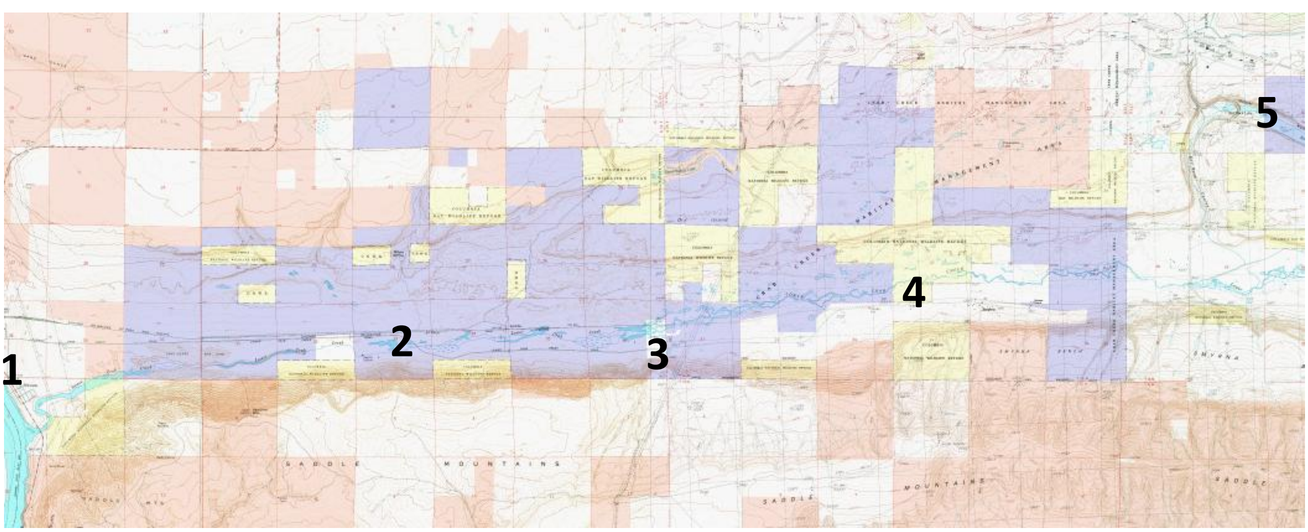


Figure 29. Public lands in the lower Crab Creek area. State lands are purple, and federal lands are yellow- and peach-colored. Bold numbers represent field trip stops. Source: Caltopo.com.

Stop 4—West of Smyrna

Figure 30. World War II bombing target located amidst scabland about four miles northeast of Stop 4. Source: Google Earth Pro.

Enroute to Stop 5

Return to Lower Crab Creek Road and head east. This will take you through the small community of Smyrna, a former stop on the Milwaukee Railroad. Note the brick Smyrna School (now a private residence) in the center of the community. At about 4.6 miles, the road curves north as road E SW. Follow this road about 2.5 miles across Crab Creek Coulee and into narrow, winding Red Rock Coulee. You will parallel a remaining, active rail line of the Washington Central Railroad. At about 2.5 miles, and before ascending to the top of the coulee, turn right onto an unmarked, good gravel road and head east for just less than 1 mile to a small parking area on the edge of Red Rock Lake. This lake lies in a coulee known as Natural Corral. Park either in the small parking area or along the road.

Stop 5—Natural Corral & Red Rock Lake

Location. Welcome to Natural Corral and Red Rock Lake. We will remain near the parking area for this stop. GPS coordinates: 46.873196°N & 119.580162°W.

Red Rock Coulee & Natural Corral. Red Rock Coulee & Natural Corral are one curvilinear coulee (Figures 31 & 32) but it is doubtful that they originated as one. Red Rock is the lower portion that runs generally ~north-south but does so in sinuous fashion. Given this un-coulee shape, Bjornstad (2006) argues that Red Rock Coulee was likely a pre-flood channel draining the Frenchman Hills and Royal Slope. It was later modified by floodwaters descending Natural Corral from the Drumheller Channels. Natural Corral has more of the typical traits of a scabland coulee—generally straight, steep walled, and ~ flat floored. This flood channel ends abruptly about 2 miles upcoulee as a nearly 100 foot tall waterfall. The abrupt head of this coulee marks the position it receded to during the last flood to pass through. We call such a feature a "recessional cataract". This coulee, like Crab Creek Coulee and Jericho Coulee, likely received its flow from the Drumheller Channels to the east. Two megabars formed in this coulee system providing further evidence of flood origin (Figure 31). The upper formed on the slower inside of the channel in the lee of the coulee edge therefore is a crescent/pendant bar (Bjornstad, 2006). The lower bar formed at the mouth of Red Rock Coulee therefore I would call it a delta bar. Red Rock Lake, like many of the lakes in the lower Crab Creek area, is human-created as a result of irrigation seepage and return flows (Figure 33).

Figure 31. Red Rock Lake in Natural Corral. Note steep walls of the coulee. Source: Author, 03/30/2026.

Stop 5—Natural Corral & Red Rock Lake

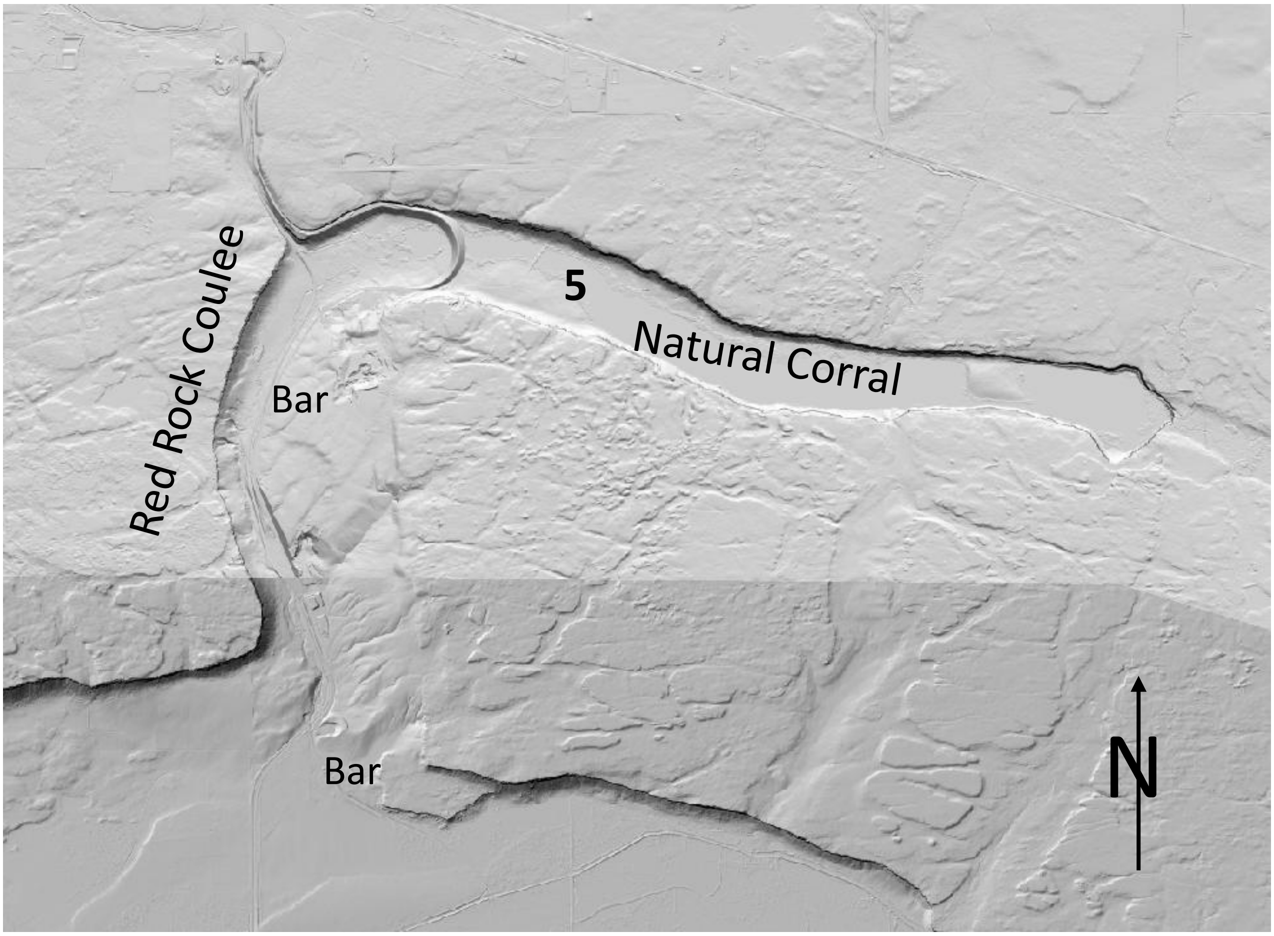


Figure 32. Lidar image of Red Rock Coulee & Natural Corral. Note the megabars in Red Rock Coulee. Bold number indicates approximate location of Stop 5. Source: Washington Lidar Portal.

Last Grand Roundup. Thousands of horses roamed the open range of the Columbia Basin at the turn of the century. With the influx of settlers and associated barbed wire fences, and the subsequent demise of the open range, wild horses were no longer seen as a resource. When ranchers from the northern Great Plains sought horses, a "last grand roundup" occurred in this area in 1906. In April, a large group of cowboys rounded up approximately 700 horses near the mouth of Crab Creek and adjacent Saddle Mountains and Frenchman Hills (Figure 33). Because of a need for feed for this many animals, the herd was moved to Red Rock Canyon and Natural Corral. As importantly, this smaller side canyon was a natural corral. "The sides are precipitous and a

Stop 5—Natural Corral & Red Rock Lake

few men can hold a large band of horses by stationing themselves at the mouth and source of the canyon. Springs furnish an abundance of water and the bottom of the coulee is covered with luxuriant bunch grass" (McIntyre, 1906). The animals were held here for several days as more horses were brought in, then the larger herd was slowly moved to Ephrata where the horses were loaded onto Great Northern Railroad freight cars headed to the Dakotas (McIntyre, 1906). By the end of the roundup in July 1906, about 5,000 horses were sent east on the Great Northern (Anglin, 1995). Other roundups would follow in 1914 and 1916 for French and British artillery horses in World War I, and in 1928, 1932, 1936, and the 1950's for canneries. However, none of the later roundups could compare with the 1906 event (Anglin, 1995).

Figure 33. Rounding up stray horses at the mouth of Crab Creek as part of the last grand roundup, April 1906. Source: Stuart McIntyre (grandson of A.A. McIntyre).

Wrap-up

Our trip today has focused on a setting of striking topography, complex geology, Ice Age flooding, and subsequent mass wasting and dune development—all in one of the most arid portions of Washington state. It is also a setting that has impacted and been impacted by human activity including railroading, ranching, military training, and irrigated agriculture. That human impact continues to shape Crab Creek and surroundings.

I hope you have enjoyed this field trip. If you have questions or comments feel free to email me at lillquis@cwu.edu. I hope you can join us on our next outing.

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