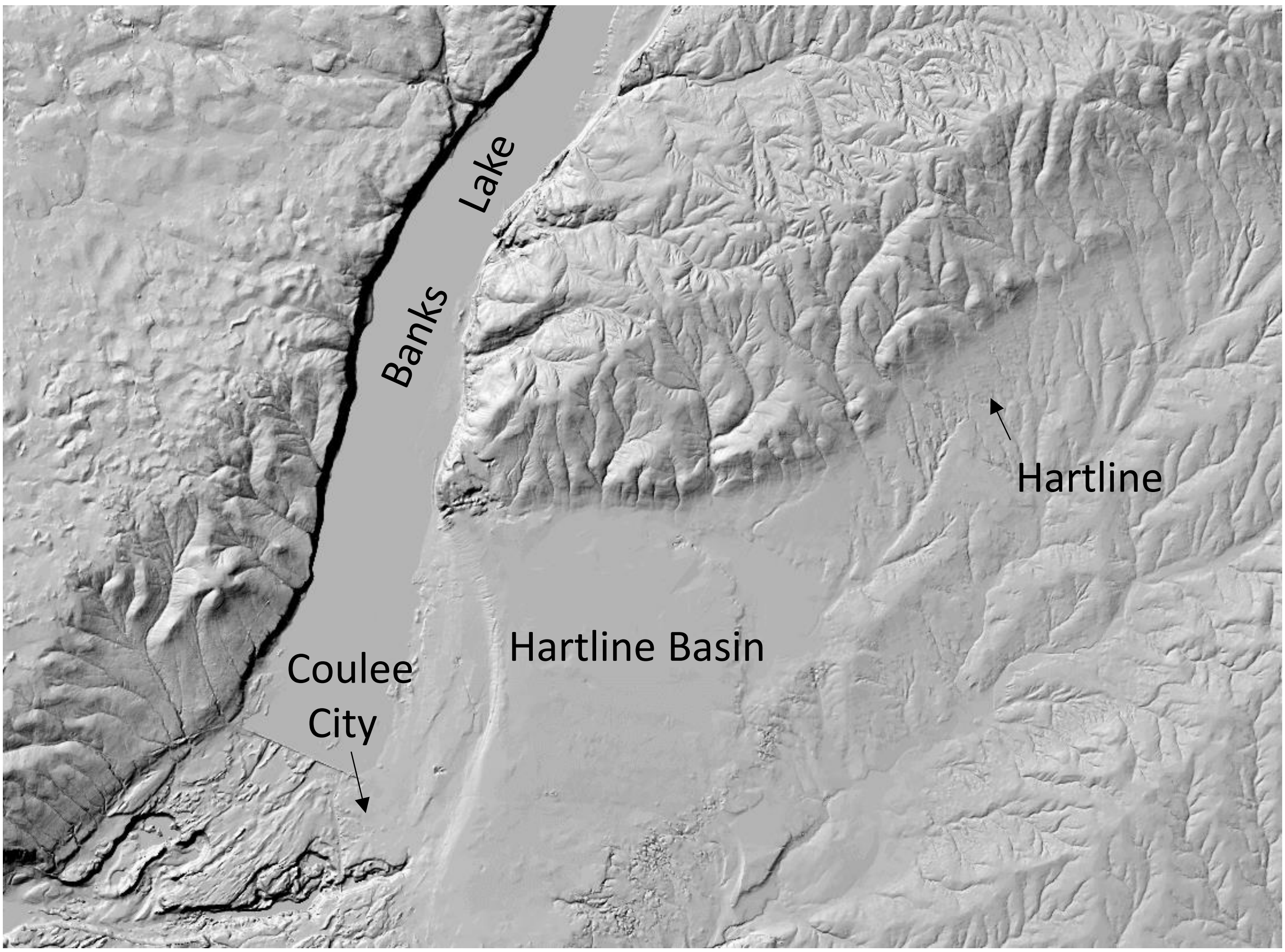
Ellensburg Chapter Ice Age Floods Institute

East of Coulee City Field Trip



Field Trip Leader:

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Geography Department, Central Washington University

November 1, 2025

Field Trip Overview

Welcome to the Coulee City area! This Ellensburg Chapter of the Ice Age Floods Institute field trip is a companion trip to other field trips we have offered in the area (e.g., Upper Grand Coulee, Northrup Canyon and Steamboat Rock, South of Coulee City, East of Moses Coulee, and Ice Age Lakes in the Grand Coulee—see my website--https://www.cwu.edu/academics/geography/_documents/karl-lillquist.php). The area east of Coulee City is relatively little studied in relation to other parts of the Channeled Scablands. This trip will focus on six stops: 1) Upper Grand Coulee; 2) Coulee Monocline; 3) Hartline Basin expansion bar; 4) “Hartline Hills” I; 5) “Hartline Hills” II; and 6) Hartline Basin scablands. Throughout our field day, we will emphasize connections between elements of the physical environment and human activity.

Tentative Schedule

10:00am	**Stop 1—Upper Grand Coulee (from Coulee City Community Park)**
10:45	**Depart**
11:00	**Stop 2--Coulee Monocline**
11:45	**Depart**
12:00	**Stop 3—Hartline Basin Expansion Bar**
12:45	**Depart**
1:00	**Stop 4—Top of ”Hartline Hill”**
1:45	**Depart**
2:00	**Stop 5—Mid-slope ”Hartline Hill”**
2:45	**Depart**
3:00	**Stop 6—Hartline Basin Scablands**
4:00	**Depart**

Getting to Stop 1

Stop 1 is located on the peninsula at the north end of Coulee City Community Park and is readily accessible from US 2. The approximate GPS coordinates of this stop are 47.618946°N & 119.292759°W.

Our Field Stops

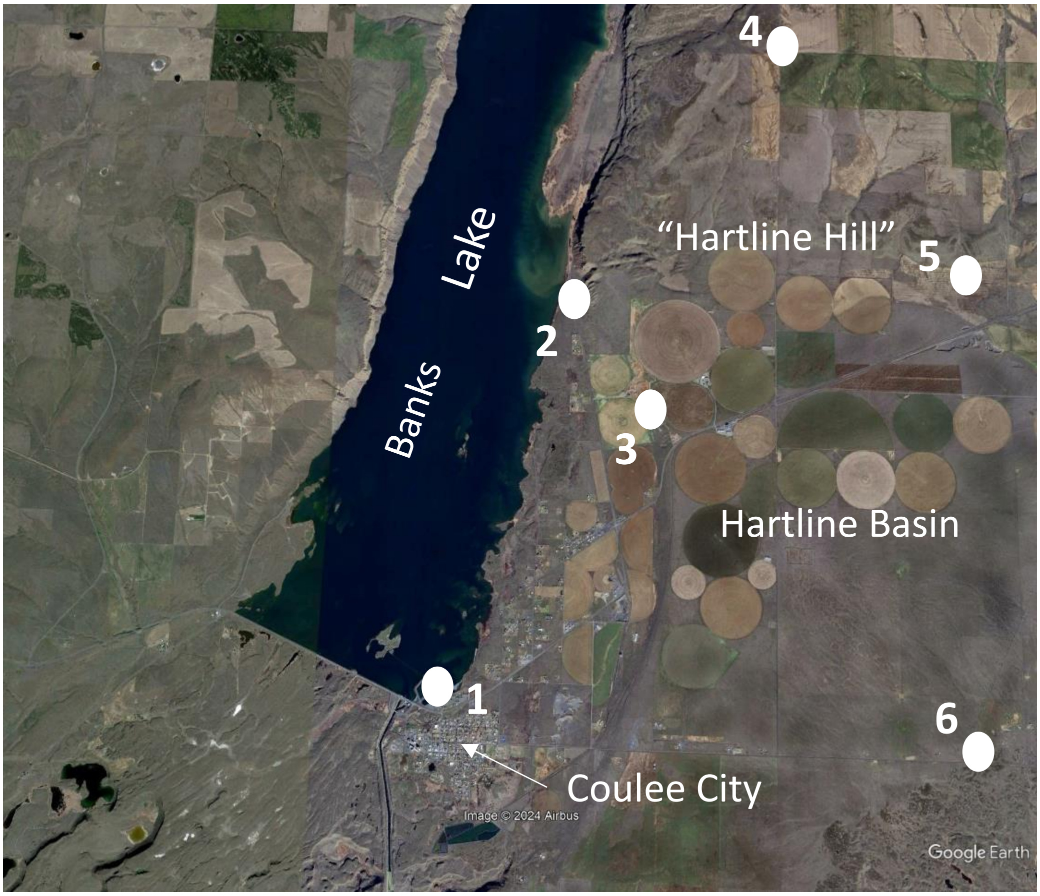


Figure 1. The approximate locations of East of Coulee City field trip stops noted with white dots and numbers. Source: Google Earth Pro, 02/25/2024.

Stop 1—Upper Grand Coulee

Location: We will meet on peninsula at the north end of Coulee City Community Park. The peninsula offers a good view of the Upper Grand Coulee and Coulee Monocline (Figure 1) . This is an information and restroom stop.

Stop 1—Upper Grand Coulee

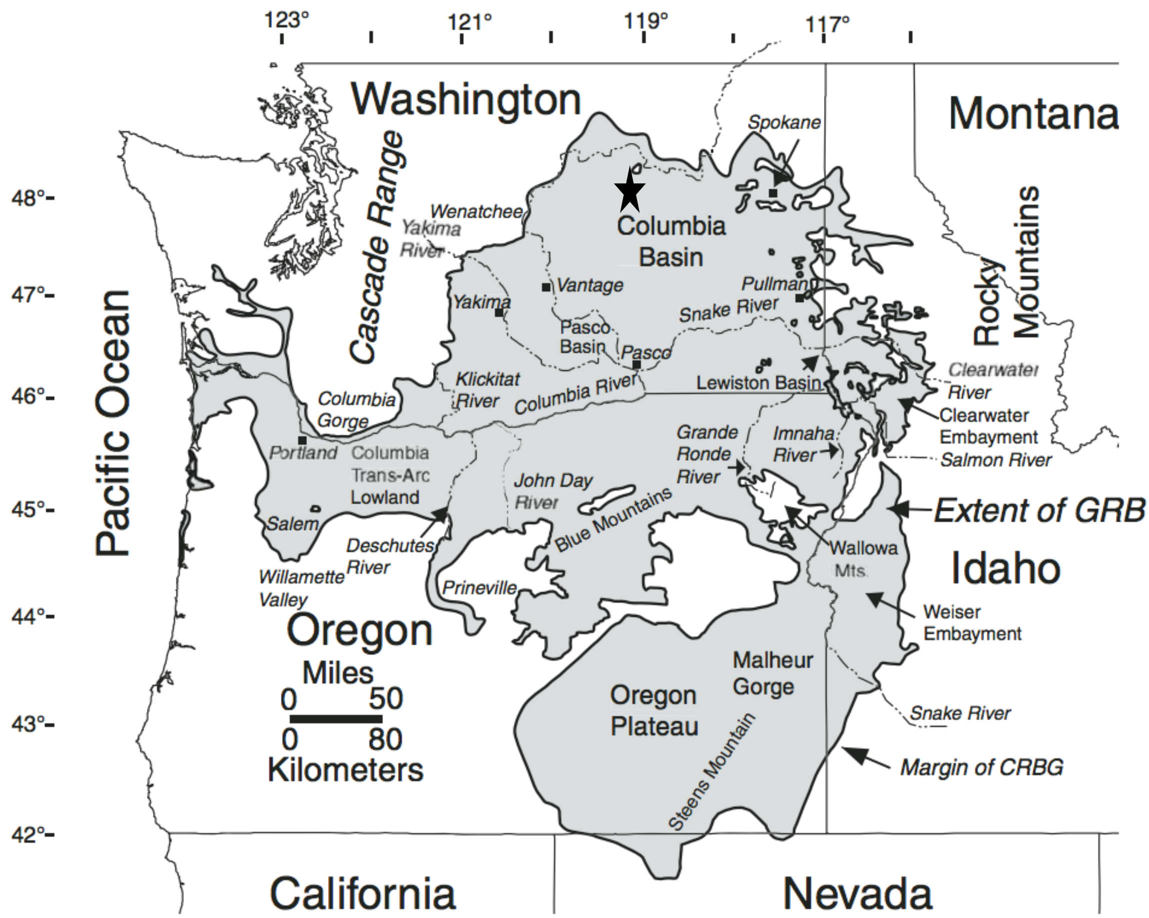


Figure 2. The extent of the Columbia River Basalt Group in Washington, Oregon, Idaho, and northern Nevada. Star indicates approximate location of field trip area. Source: USGS Cascade Volcano Center (https://www.usgs.gov/media/images/columbia-river-basalt-group-map-shows-main-regions-basalt-exposu).

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 2). More specifically, much of our day will be spent atop the Grande Ronde and Wanapum Basalts that were deposited between about 16.5 and 14.5 million years ago (ma). Of the Wanapum Basalts, we will be among the Priest Rapids, Roza, and Frenchman Springs members (Figure 3) (Gulick and Korosec, 1990). Each member is a different basalt flow, and as you can see by Figure 3, many flows compose the entire Columbia River Basalt Group.

Stop 1—Upper Grand Coulee

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		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		
				Member of Mt. Horrible		
			Picture Gorge Basalt	**Member of China Creek**		N_1
				Member of Downey Gulch		
				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 3. 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—Upper Grand Coulee

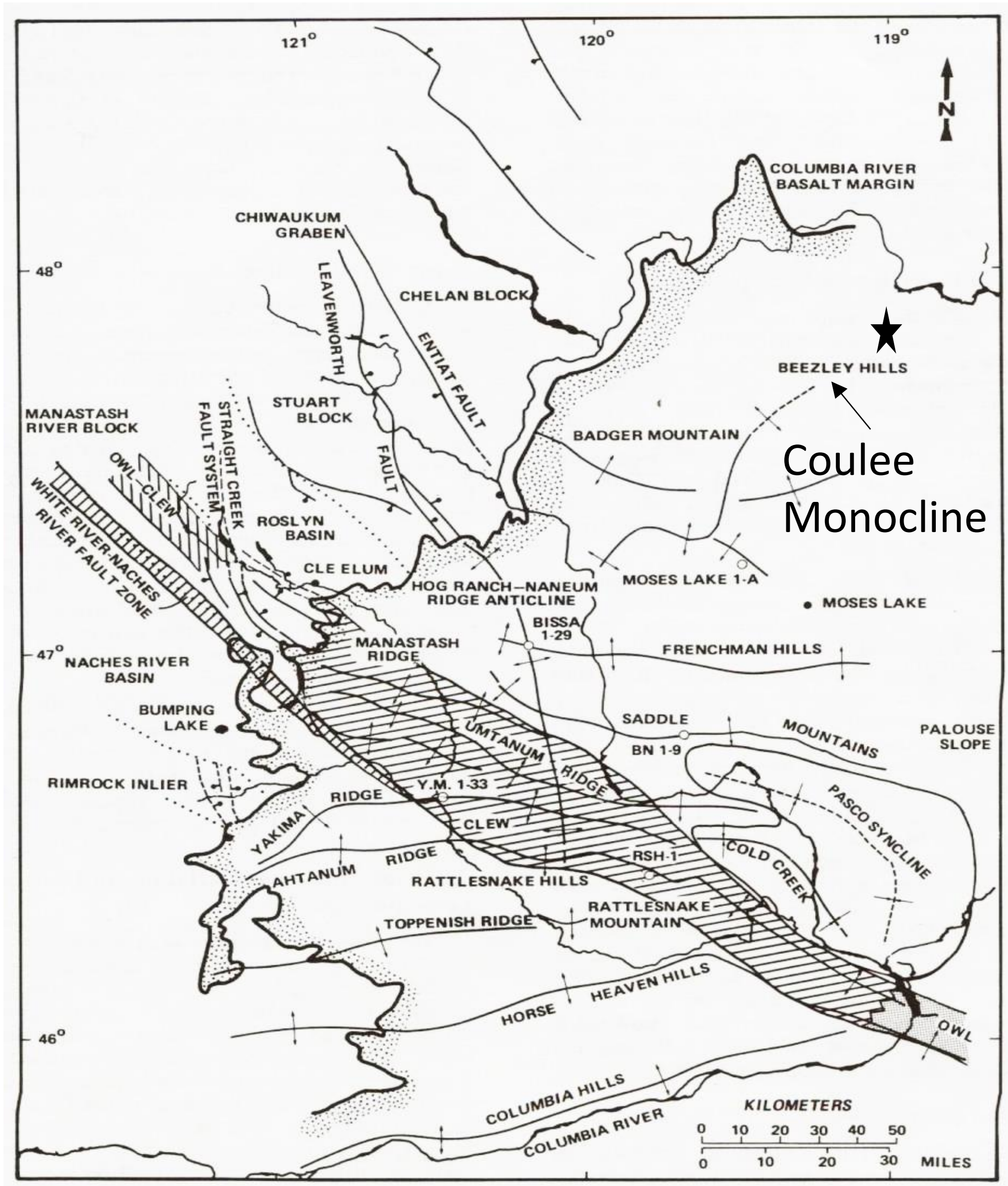


Figure 4. Generalized map of major faults and folds along the western margin of the Columbia Plateau and Yakima Fold Belt. Star indicates approximate location of field trip area. Source: Reidel & Campbell (1989, p. 281).

Structural Geology. The basalts were initially deposited horizontally or nearly so. Since deposition, they have been folded and faulted on the distal edges of the Yakima Fold and Thrust Belt (Figure 4). The ridge to our north—the Coulee Monocline-- is one of those folds. Floods down the Lower Grand Coulee followed the weakened rocks of this fold; conversely, floods in the Upper Grand Coulee flowed over and across the monocline. This feature will be the focus of Stop 2.

Stop 1—Upper Grand Coulee

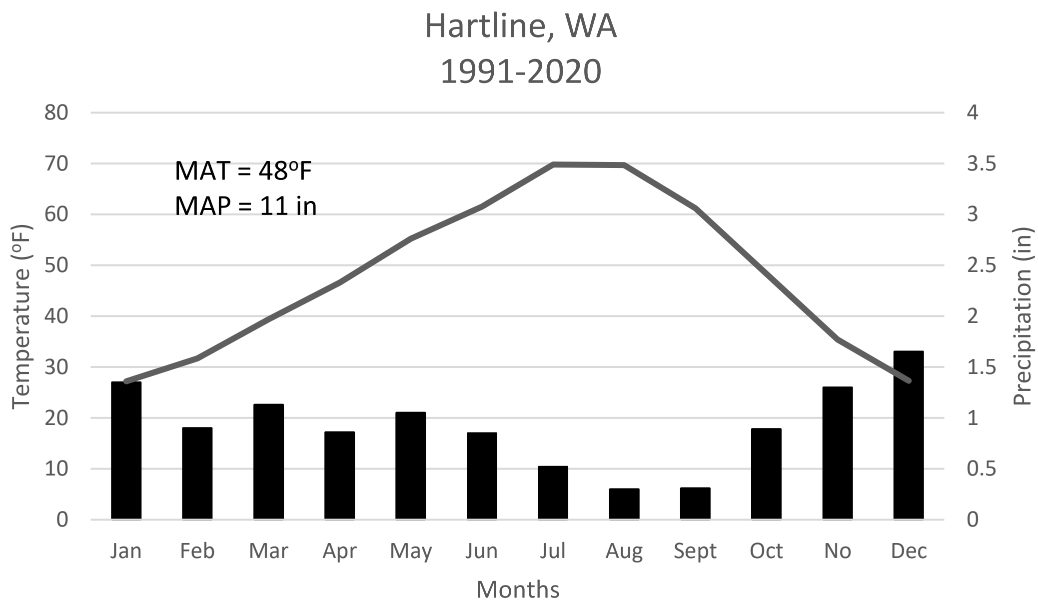


Figure 5. Modelled temperature (line graph) and precipitation (bars) for the Hartline area over the 1991-2020 climate normal. Note the sharp contrast between winter and summer temperatures, and the marked low summer precipitation. From PRISM Climate Group website (https://prism.oregonstate.edu/explorer/).

Climate. The climate of the area may be characterized as a mid-latitude dryland (Figure 5). 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 even slightly lower than more continental Spokane. The location in the rainshadow of the Cascade Range results in overall drier conditions (~11 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 northwest winds dominating in the winter and southwest winds in the summer. Given the dry and windy setting, potential evapotranspiration is likely more than twice that of precipitation (Donaldson and Ruscha, 1975).

Stop 1—Upper Grand Coulee

Glacial Lake Missoula and its Floods: The floods that shaped this landscape likely came from Glacial Lake Missoula in western Montana (Figure 6). 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 2000 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 6). We are located in the most prominent portion 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.

Coulees. Key features of the Channeled Scablands are "coulees". Coulee is a French term meaning "to flow". It refers to a variety of landforms across North America. It has been used to refer to steep-sided, channels or valleys in the northern U.S. In the southwestern U.S., it may be synonymous with "arroyo", "dry gulch", "dry channel", and "wadi" (Fairbridge, 1968). Here, it refers to steep-sided, ~flat-floored, ~straight, often dry valleys eroded into basalt bedrock by the waters of Ice Age floods.

Bretz in the Area: J Harlen Bretz, a geologist at the University of Chicago from 1914 until 1947, spent ample field time researching the area around Coulee City in 1922 (Bretz, 1922), 1923 (Bretz, 1923a), and 1927 (Bretz, 1927). He and his students examined not only the Grand Coulee but also each of the key landforms we will examine today including the Coulee Monocline, Hartline Basin, and the scablands on the south end of the Hartline Basin.

Stop 1—Upper Grand Coulee

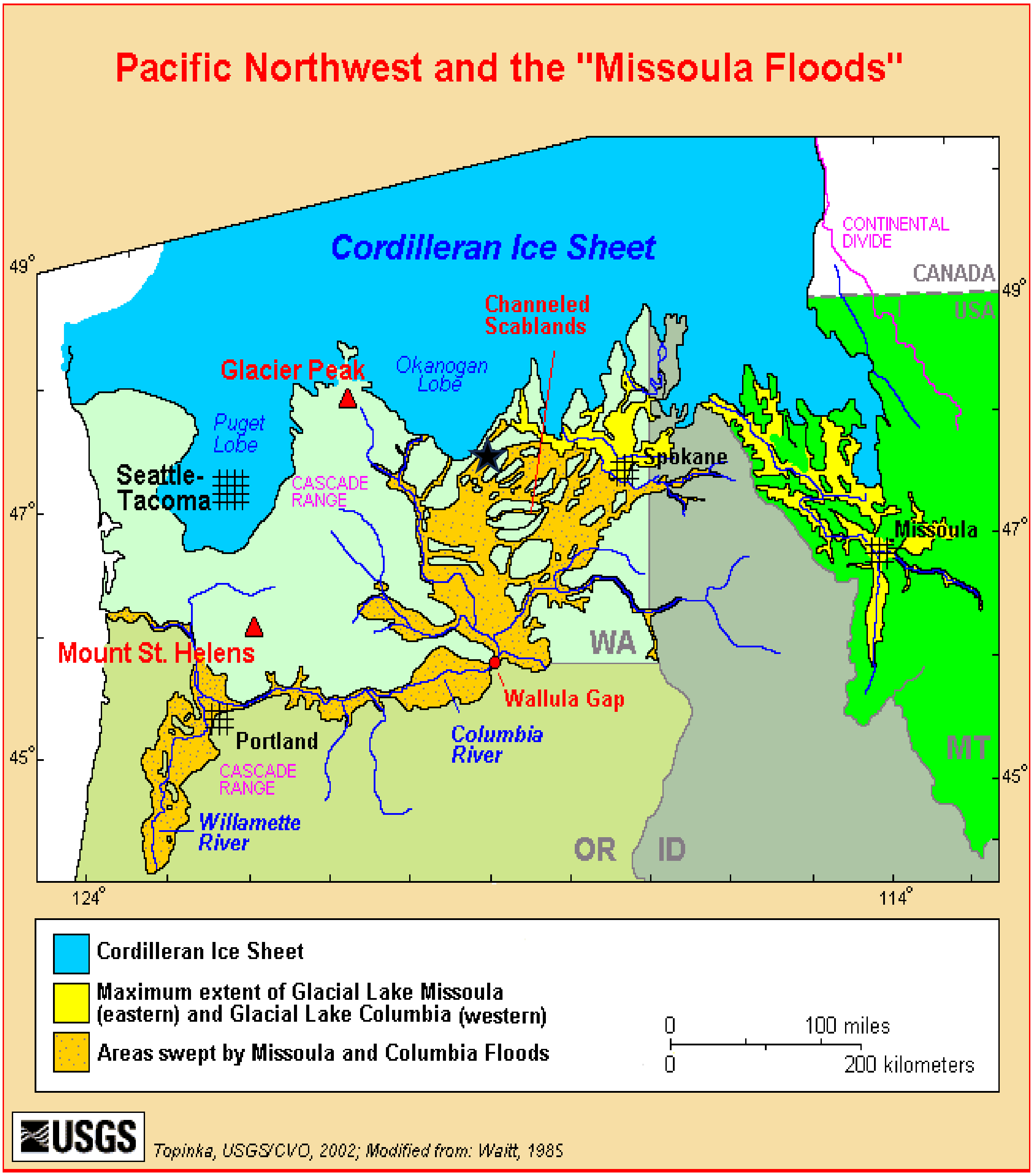
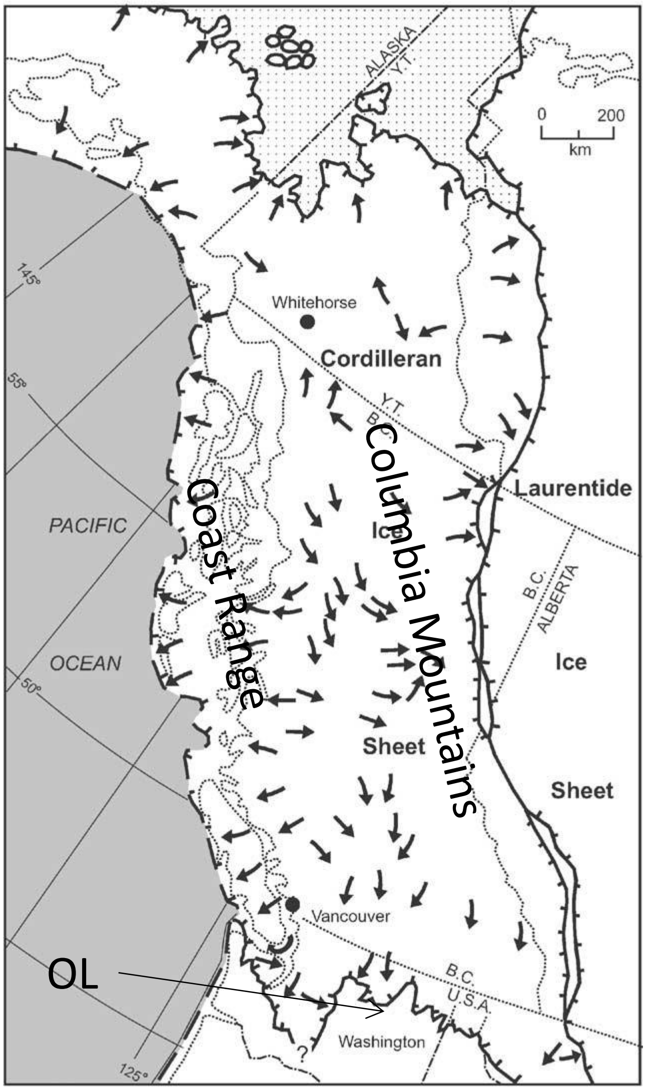


Figure 6. Map of the late Pleistocene Cordilleran Icesheet and Missoula Floods in the Pacific Northwest. Star indicates approximate location of the field trip. Source: Cascade Volcano Observatory website, https://www.usgs.gov/media/images/pacific-northwest-and-missoula-floods.

Stop 1—Upper Grand Coulee



Okanogan Lobe. While the Waterville Plateau can be cold and snowy in the winter months, and was colder and perhaps snowier in the Late Pleistocene Ice Ages, it was not sufficiently so to create glaciers <u>here</u>. The Okanogan Lobe that shaped this landscape formed in the colder and snowier Coast Mountains and Rocky Mountains of British Columbia, then moved south to near here (Bretz, 1923; Clague and James, 2002) (Figure 7). As it grew, it flowed away from its mountain sources into adjacent valleys. In addition to the Okanogan Lobe, four other lobes existed—Puget (to the west), and the Columbia River, Purcell Trench, and Flathead to the east (Figure 6).

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

Okanogan Lobe of the Cordilleran Icesheet & 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 6). 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 (more than 90 floods) of varying magnitudes passed through the Upper Grand Coulee during the late Pleistocene. Many more may have come through during earlier glacial periods (Waitt & others, 2021).

Stop 1—Upper Grand Coulee

Banks Lake. Banks Lake (Figure 1) is a reservoir in the Upper Grand Coulee impounded here by Dry Falls Dam and by the North Dam near Electric City. US 2 just west of here is on this earth fill dam. Water filling the lake is pumped up from the Columbia River (impounded as Lake Roosevelt) about 30 miles north of here. Banks Lake water is then released via the Main Canal at Coulee City to flow south providing the irrigation water for the 670,000 acre Columbia Basin Irrigation Project (CBIP) focused on the Quincy Basin, Royal Slope, and Pasco Basin. The infrastructure for the CBIP was constructed beginning in the 1940s and the first water was pumped into Banks Lake in 1951 (Neff, 1989).

Enroute to Stop 2

***Coulee City Community Park to US 2/WA 155 junction**: From the Coulee City Community Park, head northeast then northwest for just over 2 miles to the junction of US 2 and WA 155. Coulee City is a town that owes its origins and continued existence to water, agriculture, the U.S. government, and transportation. The town formed here because of the presence of McEntee Springs. Since 1952, Banks Lake has been a source of recreation, hence tourism dollars for the town. The town has long served as an agricultural center and is the nearest railhead for area farmers. Coulee City was initially located at the junction of a trail that travelled the length of the Upper Grand Coulee and one leg of the Caribou Trail that ascended the Coulee Monocline onto the Waterville Plateau to the west (Anglin, 1995). During the construction of Grand Coulee Dam, Coulee City was a rail junction for a line that ran north to the town of Grand Coulee. More recently, it lies near the junctions of US 2, WA 17, and WA 155.*

***US 2/WA 155 Junction to Stop 2**: From the junction of US 2 and WA 155, proceed north on WA 155 for 2 miles. Pull off to the side of the highway near Milepost 2 taking care to make sure your vehicle is outside the white line on the highway. GPS coordinates are approximately 47.665853°N & 119.271788°W.*

Stop 2—Coulee Monocline

Location: We are located along WA 155 at milepost 2. On the east side of the highway, we will cross the fence onto Washington State land (Figure 8).
Monoclines: The Coulee Monocline is a combination "fold and thrust fault" with one inclination hence the prefix "mono" (Figure 9). This feature formed from compressive stress of basalts at a regional scale. The northeast-southwest orientation of the monocline suggests stress that was oriented generally northwest-southeast (Figure 10). This is the most prominent of a series of small folds in the area.
Homoclinal Ridges & Valleys: Because the fold is in layered rock—i.e., basalt and interbeds, the inclined beds weather and erode differently. The harder flows or parts of flows form ridges while the softer parts form valleys (Figure 11). The ridges are called "homoclinal ridges" and the valleys are "homoclinal valleys". This field stop shows classic homoclinal ridges and homoclinal valleys over a small area (Figures 12 & 13).
Age of Coulee Monocline: Wanapum Basalt flows are 60 ft thicker on the downthrown side of the monocline than on the upthrown side suggesting that the tectonic activity forming the Coulee Monocline was active during Grande-Ronde-Wanapum time (Neff, 1989) about 16.5 to 14.5 Ma. We don't know how long this activity lasted and if it is still occurring.
Coulee Monocline & Ice Age Floods: The Upper Grand Coulee formed from headward retreat of a giant waterfall that formed as Columbia River, Glacial Lake Columbia, and Glacial Lake Missoula waters tumbled over the Coulee Monocline (Bretz, 1932; Bretz and others, 1956). The retreat resulted in the removal of much of the Coulee Monocline in the flood path. We are standing on a remnant of this monocline.
Coulee Monocline & Hartline Basin: Floodwaters passing over this receding waterfall delivered sediment into Hartline Basin (see Stop 3). The Coulee Monocline forms the north boundary of the Hartline Basin and the northern extent of Ice Age flooding in the area. Irrigated farming occurs on these flood deposits while dryland farming occurs above the flood limit in the uplands to the north .

Stop 2—Coulee Monocline

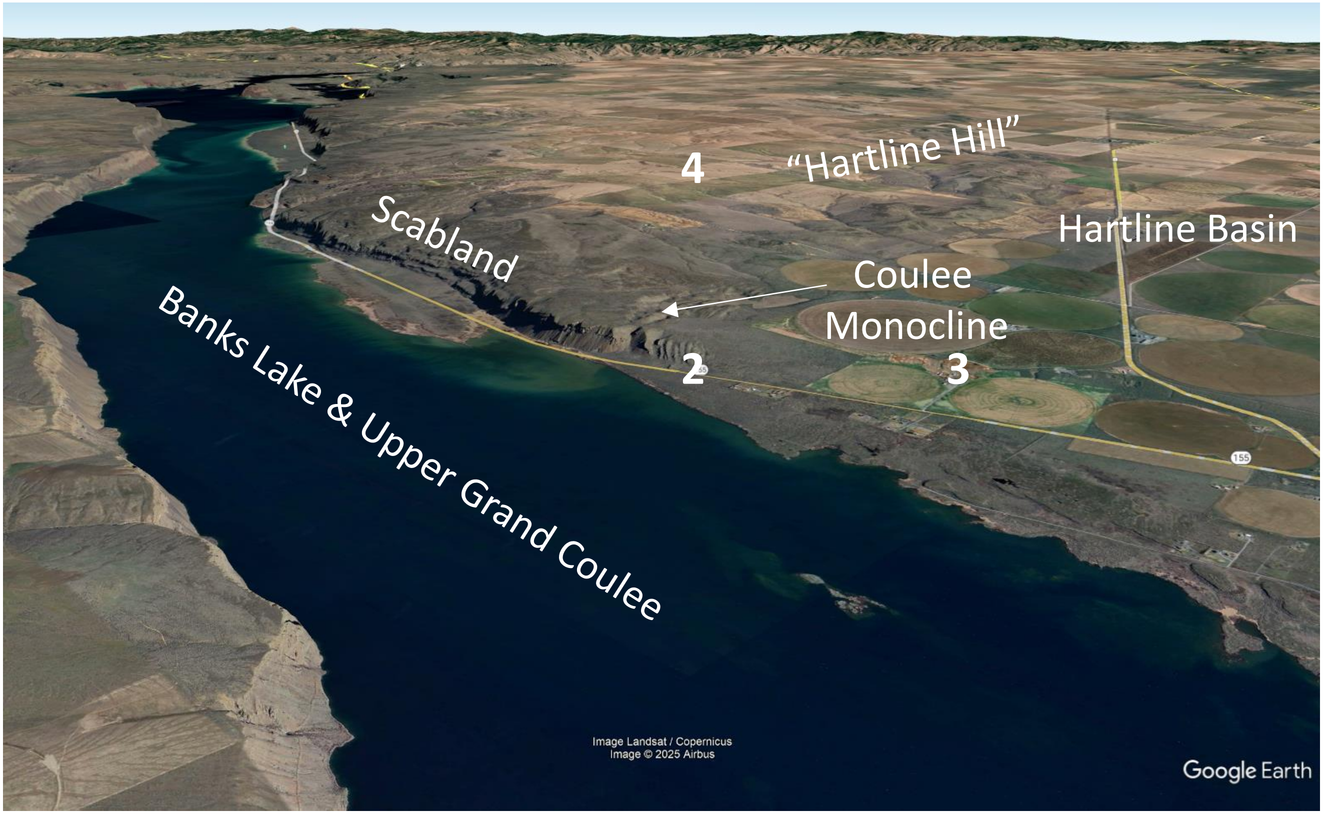


Figure 8. Oblique aerial view toward northeast of Stops 2, 3 & 4 (bold numbers). Note the homoclinal ridges and valleys of the Coulee monocline and the scabland north of the monocline. Source: Google Earth Pro, 02/25/2024.

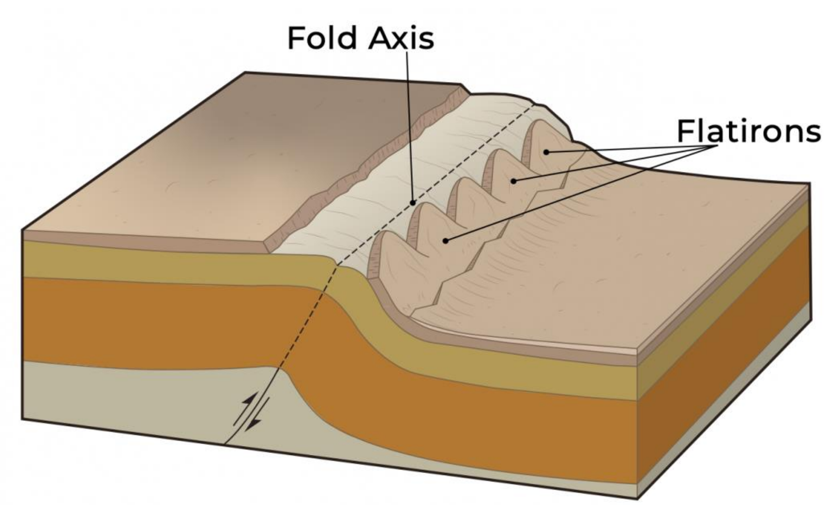


Figure 9. Block diagram of a monocline formed by folding and faulting. Source: https://geology.utah.gov/map-pub/survey-notes/geosights/geosights-raplee-ridge-san-juan-county-utah/

Stop 2—Coulee Monocline

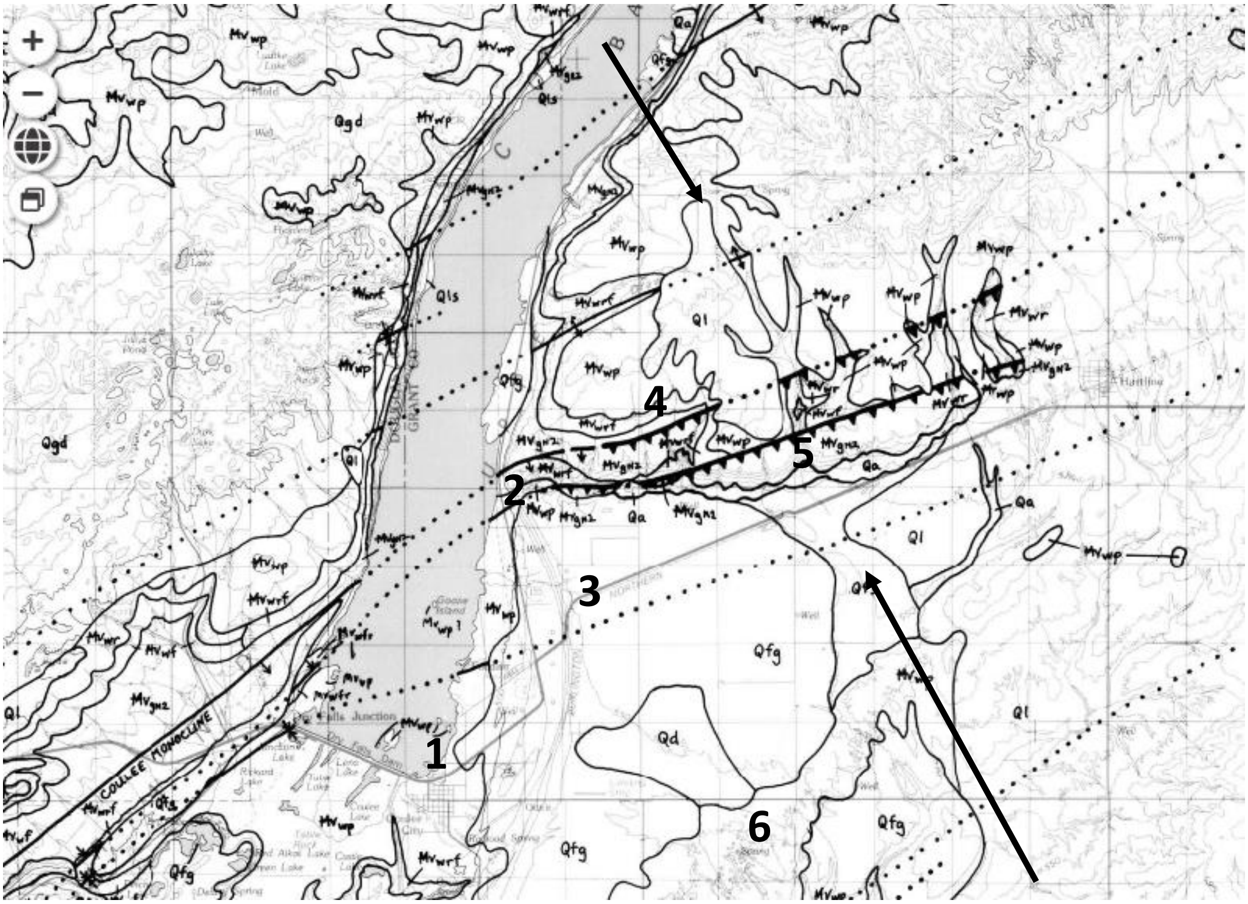


Figure 10. Geologic map of the area east of Coulee City. Note field trip stops shown with bold numbers. Bold arrows indicate general stress field. Source: Gulick & Korosec (1990).

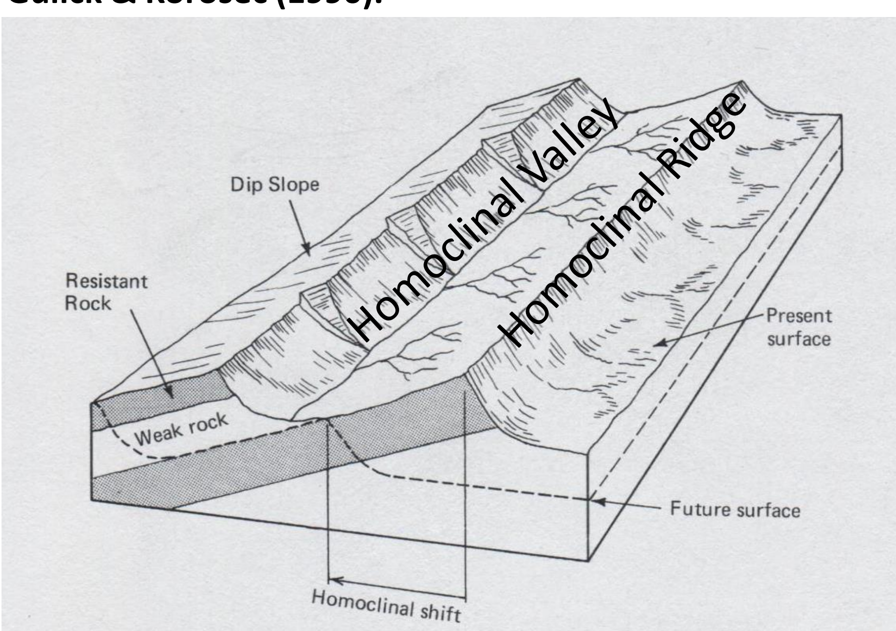


Figure 11. Homoclinal ridge and homoclinal valley model. Source: Bloom (1998).

Stop 2—Coulee Monocline

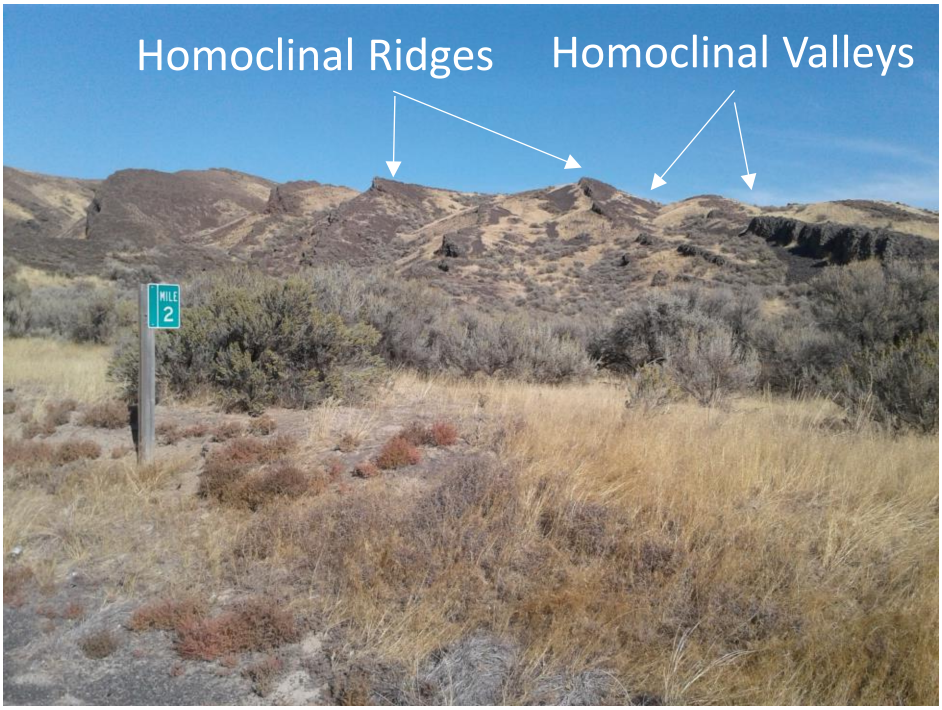


Figure 12. Side view of homoclinal ridges and homoclinal valleys of the Coulee Monocline. View from WA 155 toward northeast. Source: Author photo, October 2024.

Historical changes. The first half of the 20th century brought tremendous changes to this area. The Washington Central, a branch line of the Northern Pacific, had reached Coulee City by 1890 (Meinig, 1968). By the 1930's, a spur rail line was extended from Coulee City north to supply materials for the construction of Grand Coulee Dam (Figure 13). As noted earlier, water arrived in the Upper Grand Coulee from the Columbia River beginning in 1951. This water formed Banks Lake which inundated the coulee floor covering numerous small saline and freshwater lake as well as the original highway and railroad to Grand Coulee (Figure 13). It also inundated orchards that had originally been planted in 1906 (Figure 13). Irrigation water for these orchards came from freshwater springs, ponds, and shallow wells. By 1910, the orchards had grown to over 300 acres and included apples, pears, cherries, plums, and peaches. That year, 90 rail car loads of fruit were shipped from Coulee City. Soon after, it was said that one of those orchards was the largest D 'Anjou pear-producing orchard in Washington state (Lillquist, 1969).

Stop 2—Coulee Monocline

Figure 13. Vertical overhead view of Coulee Monocline near Stop 2 as of 28 August 1949. Note homoclinal ridges & valleys within the area of the monocline. Also note the likely saline and freshwater lakes, a large orchard, a railbed, and the different location of the highway. The white, gullied surface is Glacial Lake Columbia sediment. Bold 2 indicates location of Stop 2. Source: AAR-10F-124 USDA Grant County, WA airphoto, available on the Central Washington Historical Aerial Photograph site (https://www.gis.cwu.edu/historical_airphotos/).

Enroute to Stop 3

Stop 1 to WA 155/US 2 Junction: Retrace route south 2 miles to junction of WA 155 and US 2. Turn left onto US 2 and follow it east for nearly 1 mile ascending an escarpment. At the top of the escarpment, turn left onto an unsigned gravel road and proceed north for ~0.25 mile. Park alongside the gravel road. This is private property. Please treat it with respect and do not access it without owner permission. GPS coordinates are: 47.651160^{o}N & 119.254950^{o}W.

Stop 3—Hartline Basin Expansion Bar

Location: We are located on the west edge of Hartline Basin expansion bar (Figure 8). We will walk into the gravel quarry near where we parked.

Hartline: The Hartline Basin is named for the main community of the basin—Hartline—which, in turn, was named for John Hartline, a prominent landowner in the area (Works Progress Administration, 1941; Kirk & Alexander, 1990). The small town of Hartline developed along the Washington Central, a branch line of the Northern Pacific Railroad that came west from Cheney by 1890 (Meinig, 1968).

Bretz in the Hartline Basin: Bretz and students travelled to Coulee City on August 13, 1922 via the Washington Central Railroad. His observations are as follows: *At Hartline and westward to the edge of the sharper descent to Coulee City, there is a broad apparently dead level valley flat, miles in diameter. Smaller valleys in it show that at Hartline it is composed of alluvium or silt or loess. Nearer Coulee City and hard against the hills to the north, it is composed of gravel…Looks very much as tho [sic] a structural basin existed here and had been filled* (Bretz, 1922, p. 21).

On August 16th, he and the students returned to Coulee City and further described the Hartline "Gravel Flat": *The Hartline Flat is a great gravel and silt deposit, extending northeastward between two broad upwarps of the basalt which strike in the same general direction. It was deposited in the Coulee City structural basin, and originally must have extended westward from the present scarp above described, to the west side of the broadened portion of the Grand Coulee Valley.*

Stop 3—Hartline Basin Expansion Bar

Expansion Bars: Bars, in a landform sense, form beneath flowing water. The size of bars corresponds to the size of streams and rivers that created them. Many types of giant bars are found in the Channeled Scablands providing supporting evidence for huge floods shaping this landscape (Figure 14). We are standing on one type of giant bar—an expansion bar (Figure 15). Expansion bars form when flowing water leaves the confines of a channel and spreads out into a broader area where the lower velocity waters deposit their sand and gravel loads, often as foreset beds (Figure 16). That is what happened here: giant floods descending the Upper Grand Coulee spread out into a structural depression created by folding and faulting upon leaving the confines of the coulee near the Coulee Monocline depositing as much as 250 feet of sediments here (Bretz, 1923b). The elevation of the bar (~1790 feet) here versus the floor of the upper Grand Coulee nearby (~1490 feet) suggests floodwaters were at least 300 feet deep here (Figure 17).

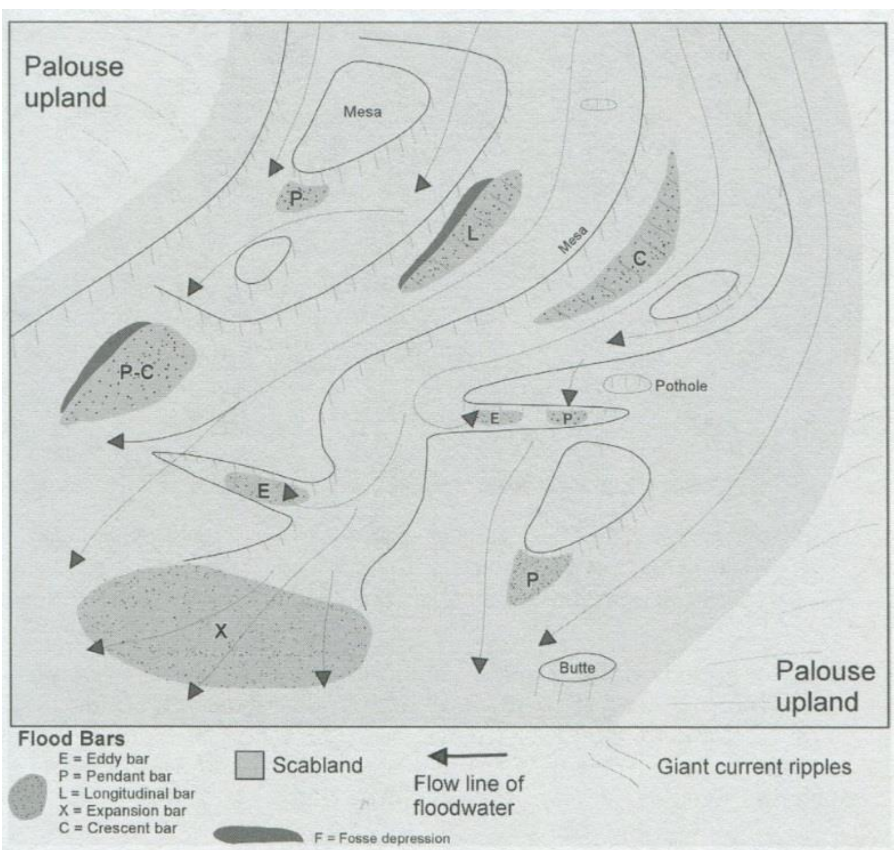


Figure 14. Types of flood bars. From Bjornstad & Kiver (2012, p. 51).

Stop 3—Hartline Basin Expansion Bar

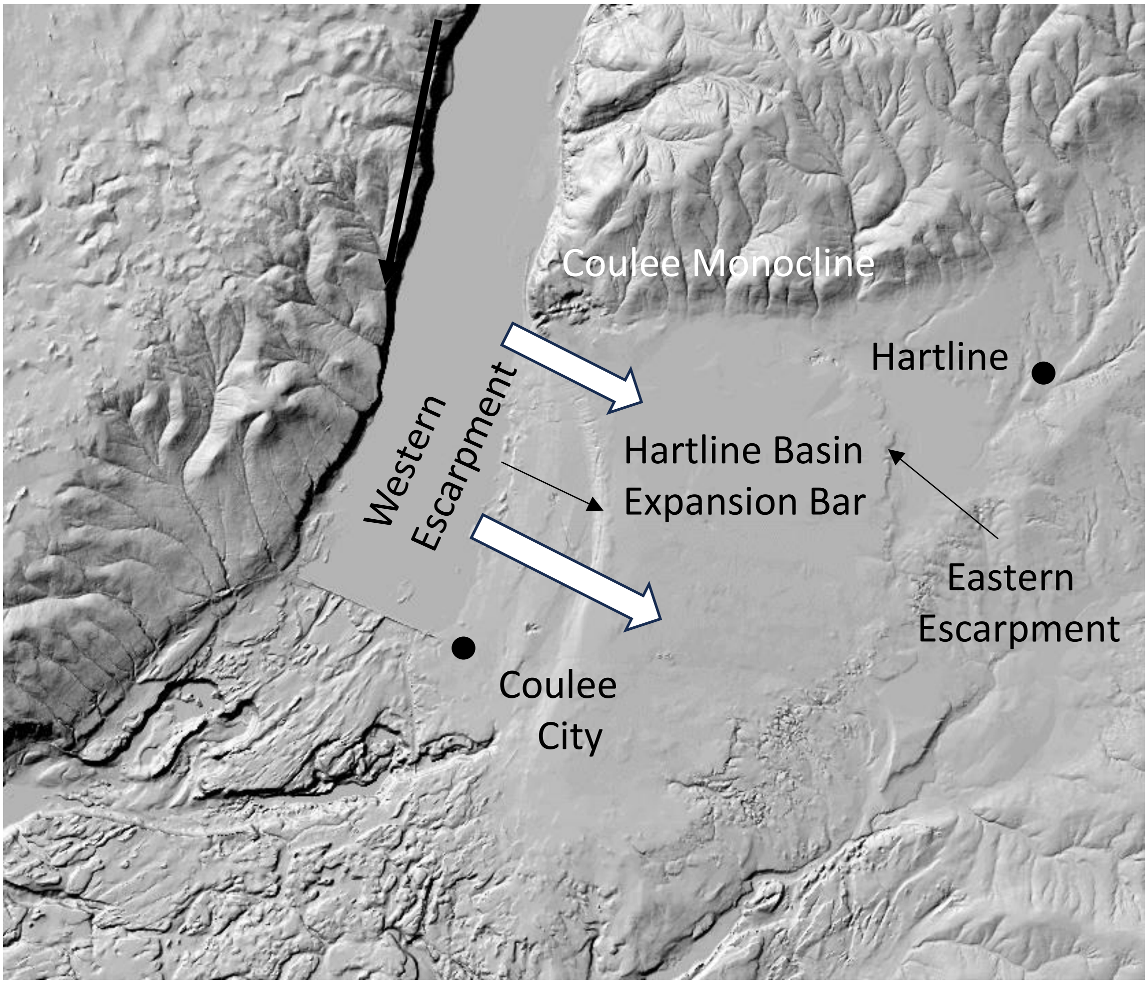


Figure 15. Hartline Basin expansion bar, Coulee Monocline, and western and eastern escarpments in relation to Coulee City and Hartline. White arrows indicate flood flow into the Hartline Basin. Source: Caltopo.com

Composition: Bretz (1932) identified the sediments of the Hartline Basin as the "Hartline Basin Gravel". The Hartline Basin expansion bar is composed of angular to subangular basalt gravels and sands (Figures 10 & 17). This dominantly basalt composition suggests that the bar was built before the upper Grand Coulee had receded into the granitic rocks in the vicinity of Steamboat Rock (Bjornstad and Kiver, 2012). Southeastward dipping foreset beds (Figure 17) and eastward fining sediments in local quarries indicate that the basalt gravels originated in the Upper Grand Coulee (Bretz, 1923).

Stop 3—Hartline Basin Expansion Bar

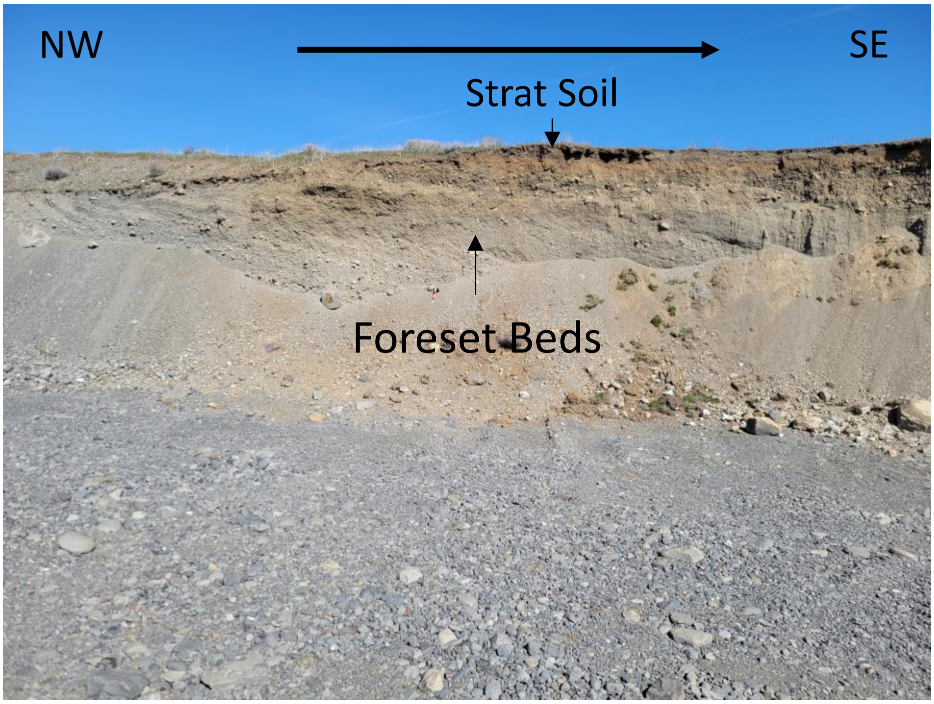


Figure 16. Foreset beds in gravels and sands of Stop 3 gravel quarry. Arrow indicates interpreted flow direction. Also, note poorly developed Strat soil atop outcrop. Source: author photo, 13 April 2025.

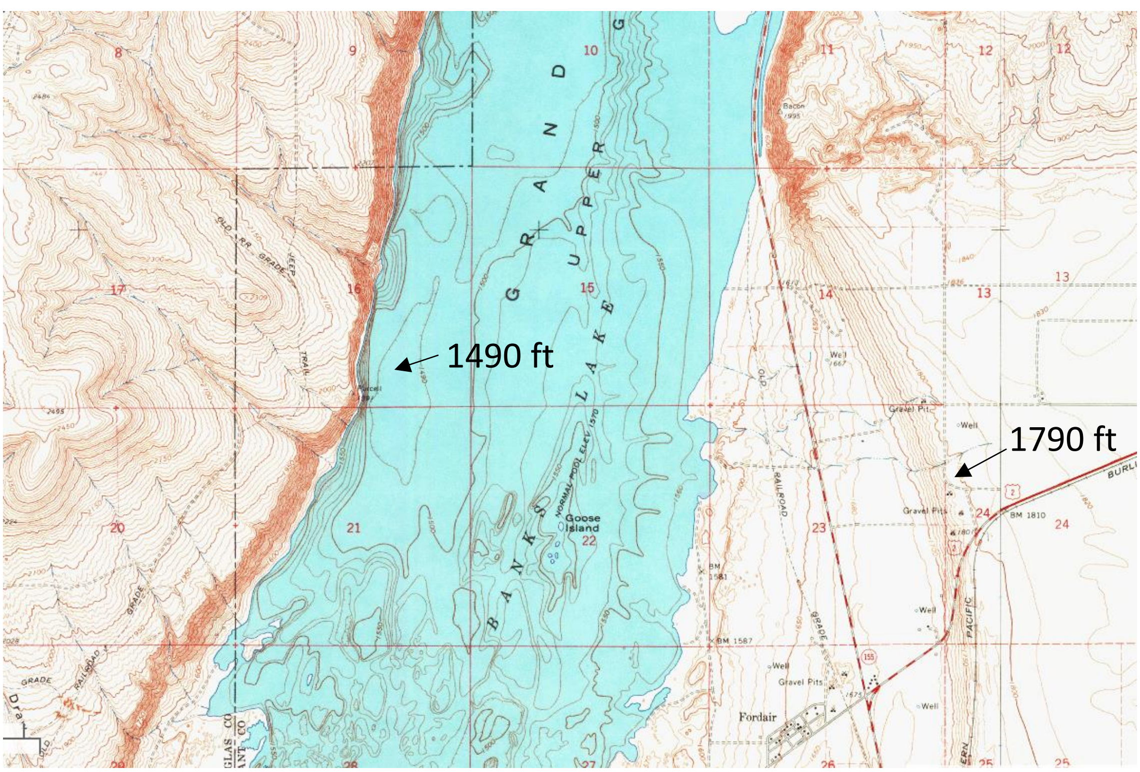


Figure 17. Elevations of the western edge of the Hartline Basin expansion bar in relation to elevations of the floor of the Upper Grand Coulee. Source: Mold and Hartline NW, 7.5' quadrangles. Accessed via caltopo.com.

Stop 3—Hartline Basin Expansion Bar

Soils Atop Expansion Bar: Common soil series formed in the sediments of the expansion bar include the Strat, Magallon, and Stratford (Gentry, 1984). Each of these series are very deep, well to excessively drained, and have coarse textures below a loess (windlblown)-derived, silt loam mantle. The details of the Strat Series mapped at the site are shown below (Figures 18 & 19).

Figure 18. Strat soil exposure at the top of Ice Age flood deposits in gravel quarry at Stop 3. Note coarse nature and overall poor development of soil. Source: author photo, 13 April 2025.

STRAT SERIES
The Magallon series consists of very deep, well drained soils that formed in glacial outwash.
TAXONOMIC CLASS: Sandy, dry Mollisols (i.e., soils of dry grasslands)
TYPICAL PEDON:
A--0 to 10 inches; brown; very stony silt loam; slightly alkaline (pH 7.6).
Bw1--10 to 18 inches; pale brown; very cobbly loam; slightly alkaline (pH 7.8).
Bw2--18 to 22 inches; yellowish brown; very gravelly loam; slightly alkaline (pH 7.8).
2Bkq—22-60 inches; yellowish brown; extremely gravelly sand; slightly alkaline (pH 7.8).

Figure 19. Boiled down description of the Strat Series. Source: https://www.nrcs.usda.gov/resources/data-and-reports/official-soil-series-descriptions-osd

Stop 3—Hartline Basin Expansion Bar

Bounding Escarpments: The Hartline Basin Expansion Bar is bounded by escarpments on the western and eastern margins (Figure 15). The ~100 foot tall western escarpment indicates that larger floods created the bar and subsequent, smaller floods confined to the Upper Grand Coulee eroded the edge of the bar. We ascended this escarpment on US 2 from the junction with WA 155. We will discuss the eastern escarpment at Stop 5.
Age: To my knowledge, no one has dated Hartline Basin expansion bar sediments. However, we can get a sense of the relative ages of the bar. Bretz (1932) inferred that the Hartline Basin expansion bar had been constructed <u>before</u> Dry Falls had retreated to its present location. This was indicated by the elevation of bar deposits relative to the elevation of Dry Falls (Bretz (1923b). Bretz (1932) notes that the gravels of the expansion bar are "almost perfectly fresh" beneath a 2 ft thick zone of slightly red stained sediments. The stained gravels have not been softened by weathering. This suggests that the gravels are late Pleistocene (i.e., ~130,000 to ~11,600 years old), and that the Upper Grand Coulee was still receding northward at the time of their deposition.
Implications: Five "trimlines" present on the western escarpment may indicate erosion by the final, successively smaller floods that descended the Upper Grand Coulee at about 15,000 years (Waitt & others, 2021) (Figure 20) This large expansion bar may have once extended from the Hartline Basin west to the west wall of the Upper Grand Coulee, helping impound the south arm of Glacial Lake Columbia (Figure 21) (Bjornstad & Kiver, 2012). This bar may have impounded Glacial Lake Columbia for several hundred years but ultimately catastrophically failed sending a Missoula Flood-like torrent of Glacial Lake Columbia water down the Lower Grand Coulee in the late Pleistocene.
Because of the coarse nature of the bar sediments, much of the bar land is not suitable for dryland farming; rather, crops require irrigation on these coarse textured parent materials (Figure 20). Irrigation of the Hartline Basin began in the late 1950's and early 1960's (Brian Isaak, personal communication, 23 April 2025).

Stop 3—Hartline Basin Expansion Bar

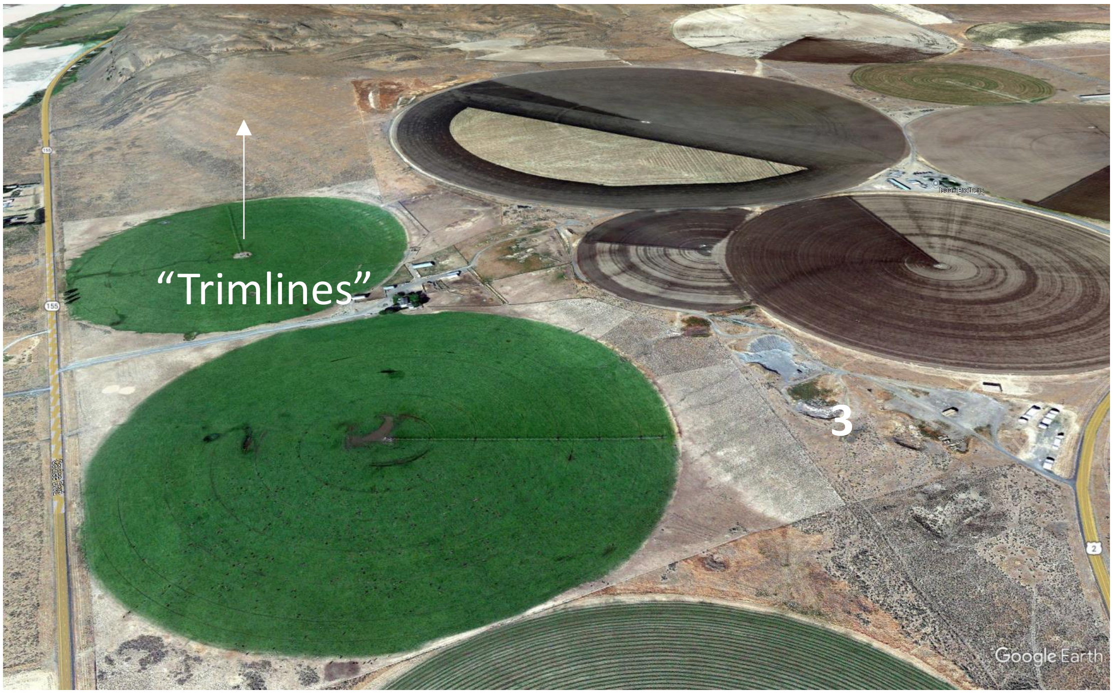


Figure 20. Five "trimlines" on the western escarpment north of Stop 3. Bold 3 indicates location of Stop 3. Source: Google Earth Pro, 9/13/2011.

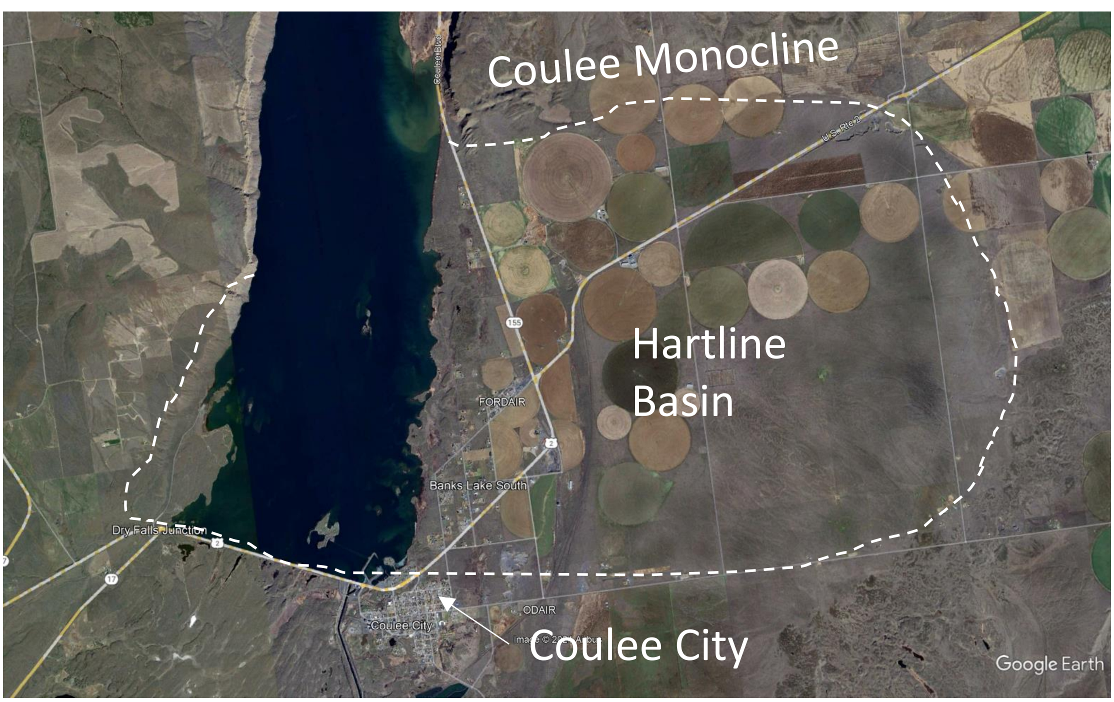


Figure 21. Possible original extent (dashed line) of Hartline Basin expansion bar. Circles are irrigated farm fields. Source: Google Earth Pro, 2/25/2024; modified from Waitt & others, 2021.

Enroute to Stop 4

Gravel quarry to US 2. Return to US 2. Turn left (east) onto US 2.
US 2 to Junction of US 2 and road L NE. Drive east on US 2 for nearly 1 mile. Turn left (north) onto gravel road L NE.
Road L NE to Stop 4. Follow road L NE north for ~3.1 miles. The road steepens as it ascends the Coulee Monocline. Turn right on road 42 NE and park near the first soil outcrop on the right. GPS coordinates: 47.699101°N & 119.231913°W.

Stop 4—Top of ”Hartline Hill”

Location: We are located atop the Coulee Monocline (Figure 22) on the “Hartline Hill”. The lands here are private property. We will remain on the road and examine the soil outcrop in the roadcut.
Maximum Flood Limit. We are located near the top of the monocline at ~2225 ft elevation. This is just above the highest identified Ice Age floods to shape the area (Figure 22). As a result, the surface we are on here should be compositionally different and older than that of the previous two field stops.

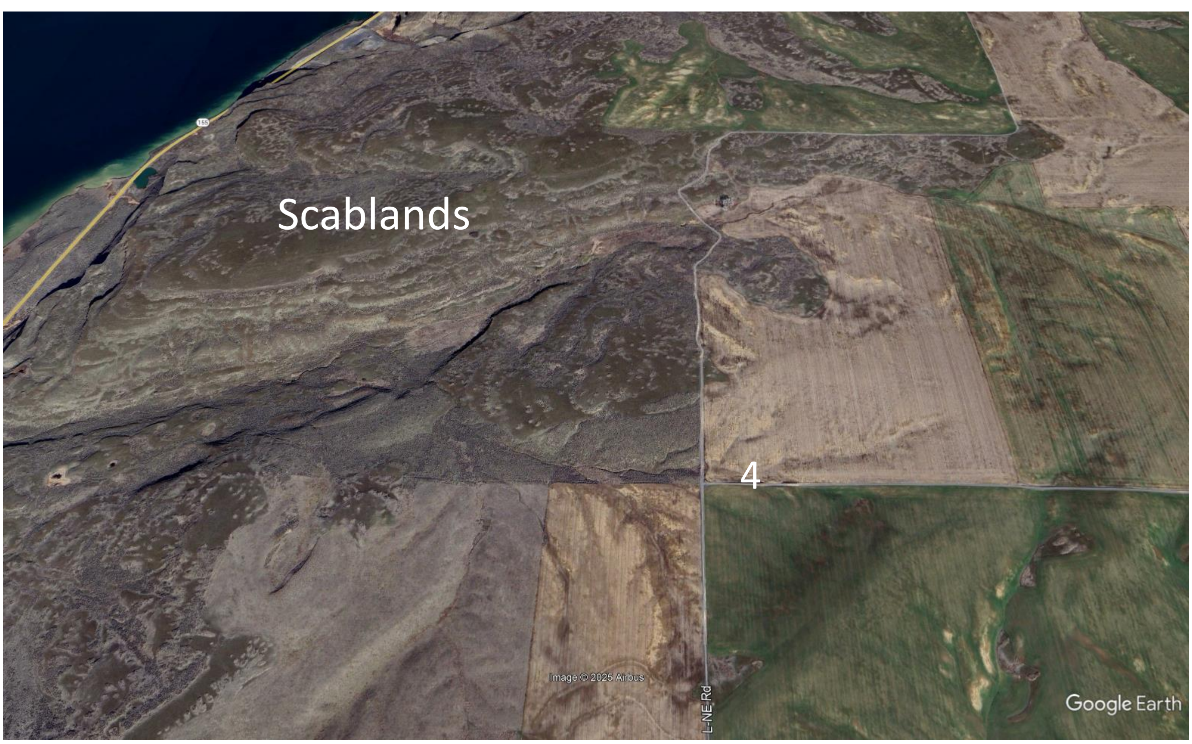


Figure 22. Oblique overhead view of Stop 4 and vicinity. Note the scablands to west and north of site. North toward top of image. Source: Google Earth Pro, 25 February 2024.

Stop 4—Top of ”Hartline Hill”

Loess: The fine textured soils present here are composed of loess (i.e., windblown sediments). Loess is characterized by silt-sized particles but often includes some fine sand and clay. The soil series present atop the Coulee Monocline in this area include the Bagdad, Renslow, and Ritzville (Gentry, 1984). Each is a very deep, well drained silt loam (Figures 23 & 24). Silt is intermediate in size to sand and clay. Its interactions with water and nutrients are also intermediate to sand and clay. This means that silt will allow water infiltration (unlike clay-rich soils) but will slow percolation (unlike sand-rich soils). These characteristics are ideal for rainfed agriculture in a semiarid setting. Additionally, loess often leads to deep soils that store more water in the rooting zone than do shallow deposits.

Where Did Loess Originate? We typically think of loess as forming downwind of glacial outwash plains. When glacial meltwater slows, it deposits its transported sediments. Once those sediments have dried, they become susceptible to the pervasive winds that characterize areas adjacent to glacier fronts. The problem here is that there doesn't appear to have been a major outwash plain to serve as a significant source of loess. A possible small, local source for the loess were the Glacial Lake Columbia sediments deposited in the Upper Grand Coulee. A large sediment source was present in the Pasco Basin where Ice Age floodwaters were ponded behind the Horse Heaven Hills. Supporting this source is the fact that loess thickness and grain size declines east and north of the Pasco Basin (Busacca & McDonald, 1994) (Figure 25).

Figure 23. More than 6 ft of loess in roadcut at Stop 4. Striped shovel is ~1.5 ft long and folding rule is ~6 ft long. Source: Author photo, 13 April 2025.

Stop 4—Top of ”Hartline Hill”

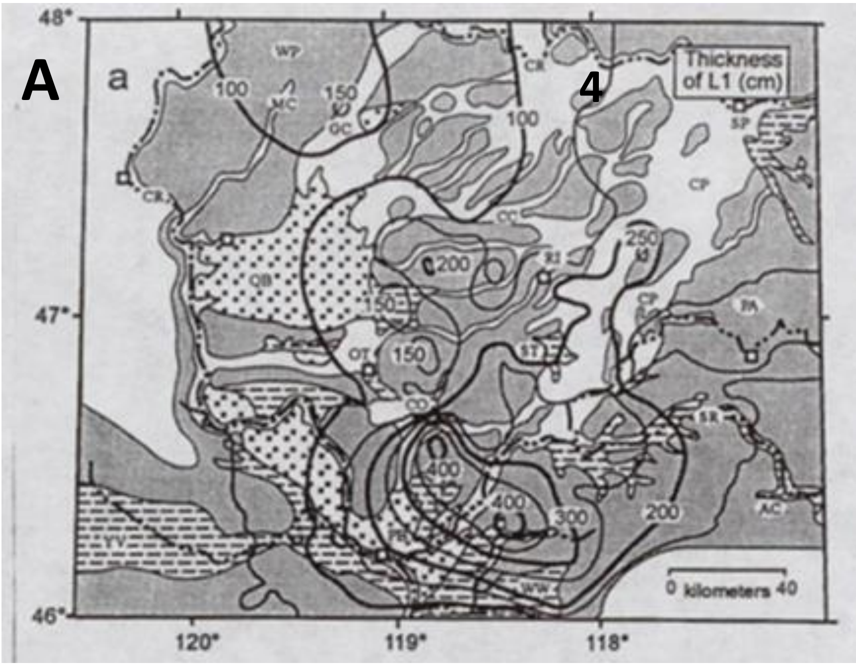
RENSLOW SERIES

TAXONOMIC CLASS: Calcium & clay rich mollisol (i.e., grassland soil)
TYPICAL PEDON:
Ap--0 to 25 cm; silt loam; grayish brown; slightly hard, very friable, slightly sticky, slightly plastic; slightly alkaline (pH 7.4).
BA--25 to 46 cm; silt loam; brown; slightly hard, very friable, slightly sticky, slightly plastic; slightly alkaline (pH 7.6).
Bt--46 to 71 cm; silt loam; brown; hard, friable, slightly sticky, slightly plastic; moderately alkaline (pH 8.2)
Bk1--71 to 97 cm; silt loam; pale brown; slightly hard, very friable, slightly sticky and slightly plastic; strongly effervescent; strongly alkaline (pH 8.6); clear wavy boundary
Bk2--97 to 117 cm; silt loam; pale brown; slightly hard, very friable, slightly sticky and slightly plastic; slightly effervescent; strongly alkaline (pH 8.8).
Bk3--117 to 155 cm; silt loam, light yellowish brown; hard, friable, slightly sticky and slightly plastic; slightly effervescent; strongly alkaline (pH 8.8)

Figure 24. The Renslow silt loam mollisol characteristic of the top of the Coulee Monocline. Source: Gentry (1984), Web Soil Survey, and https://www.nrcs.usda.gov/resources/data-and-reports/official-soil-series-descriptions-osd.

Age of the Soil. The Renslow soil here is not only finer-textured but is also much better developed than the Strat soil at Stop 3. The better development is seen in the: 1) increased number of “horizons” (i.e., layers); 2) clay accumulation (i.e., Bt) horizon; and 3) calcium carbonate accumulation (Bk) horizons (Figure 24). The calcium carbonate-rich Bk horizon is especially prominent here at the base of the soil in the roadside ditch. These three indicators of increased development suggest that this soil predates the late Pleistocene Ice Age floods. This makes sense given the location of the soil above obvious flooded scabland surfaces (Figure 22).

Stop 4—Top of ”Hartline Hill”



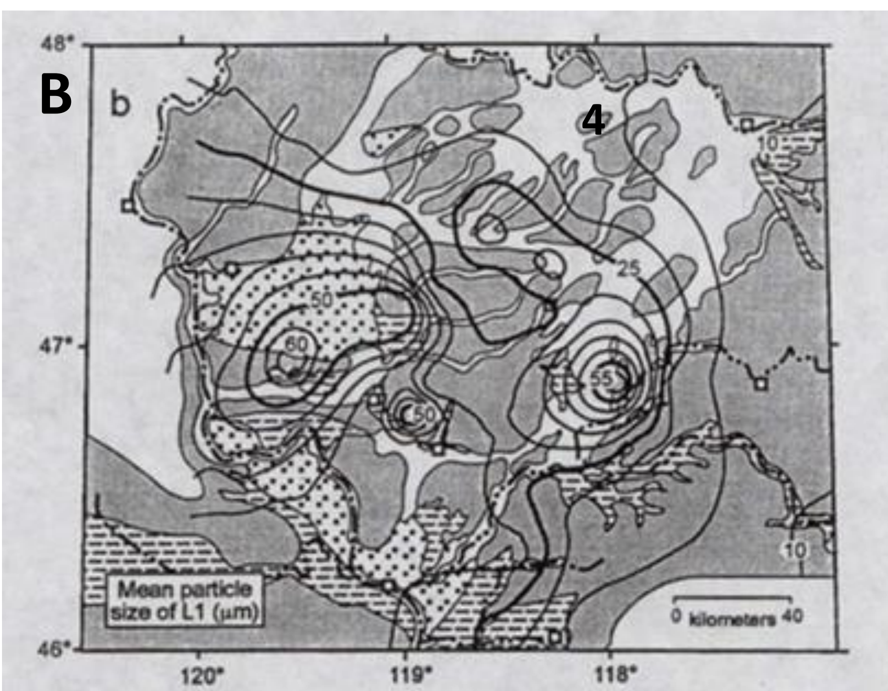


Figure 25. A. Contour map of loess thickness for L1 (more recent) loess (above). Bold contours are 100 cm intervals, thin contours are 50 cm intervals. B. Mean particle size for L1 loess (below). Bold contours are 25 micrometer intervals. Thin contours are 5 micrometer intervals. Places shown on the map include: WP = Waterville Plateau, MC = Moses Coulee, GC = Grand Coulee, PB = Pasco Basin, YV = Yakima Valley, and PA = Palouse. Approximate location of field trip stop is shown with a bold 4. Source: Busacca & McDonald (1994).

Stop 4—Top of "Hartline Hill"

Water Erosion of Loess. Water has extensively eroded these deposits over time as evidenced by the "dendritic" (i.e., like the veins of a leaf) drainage pattern (Figure 26). Because of the extensive stream channel development and associated water erosion, we can say that this area above the Ice Age flood limit is a "mature" landscape as opposed to the areas that were flooded more recently. The Universal Soil Loss Equation is a way to assess the causes and degree of soil erosion. The equation consists of several factors, one of which the susceptibility of a soil to "sheet" (i.e., water moving like a sheet) and "rill" erosion (i.e., water moving in a small channel) erosion. This is termed the "K factor" which is affected by soil texture, organic matter, the organization of soil particles into "structures", and the ease by which water moves through pores in a saturated soil (Web Soil Survey). The K factor scale ranges from 0.02 to 0.69 with larger numbers meaning higher potential soil erosion. The Renslow soil (individually and in association with other similar soils) has a rating of 0.55 indicating that it has a moderate susceptibility to sheet and rill erosion (Web Soil Survey—Soil Properties and Qualities—Soil Erosion Factors).

Erosion Control: Water and wind erosion is a big deal in loess-based soils. Erosion removes the most fertile portions of these dryland soils—the A horizons (Figure 24). Farmers, with the assistance of the US Department of Agriculture--Natural Resources Conservation Service (USDA-NRCS), try to limit erosion by keeping organic material on the soil. This is difficult to do in a semiarid area that requires that farmers leave fields fallow every other year. For conventional tillage farmers this means creating a "mulch" consisting of wheat straw and mineral soil atop the overall soil. Direct seed (i.e., no till) farmers disturb the soil surface much less than conventional tillage farmers therefore leaving a more continuous crop residue mulch atop the soil. More continuous mulch does a better job of limiting water and wind erosion.

Water Erosion Control Structures: In addition to changes in cultivation practices, water erosion can also be slowed through the construction of structures such as terraces and berms. These features are relatively common on the steep slopes of the Coulee Monocline face (Figure 26). I assume that these features were installed with the cooperation and financial assistance of the USDA-NRCS. They correspond to areas of high levels of water erosion (Figure 25) in the main soil series--Bagdad, Renslow, and Ritzville-- on the Coulee Monocline.

Stop 4—Top of ”Hartline Hill”

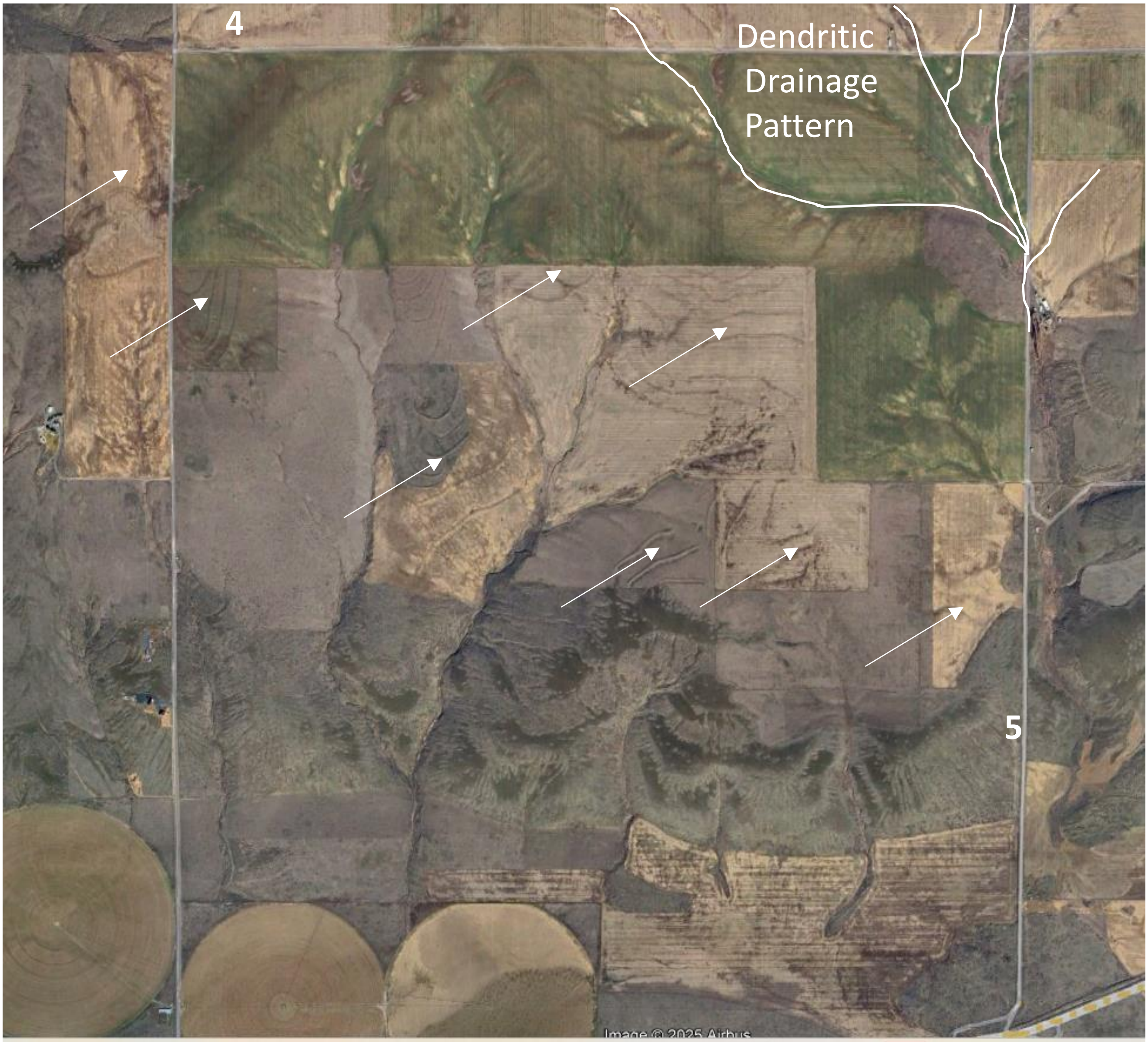


Figure 26. Location of stops 4 and 5 (bold numbers) on Coulee Monocline. Note the dendritic drainage pattern (outlined in white) indicating a “mature” landscape. Also note the numerous water erosion prevention structures (indicated by white arrows) on the steeper slopes of the Coulee Monocline. Source: Source: Google Earth Pro, 2/25/2024.

Stop 4—Top of "Hartline Hill"

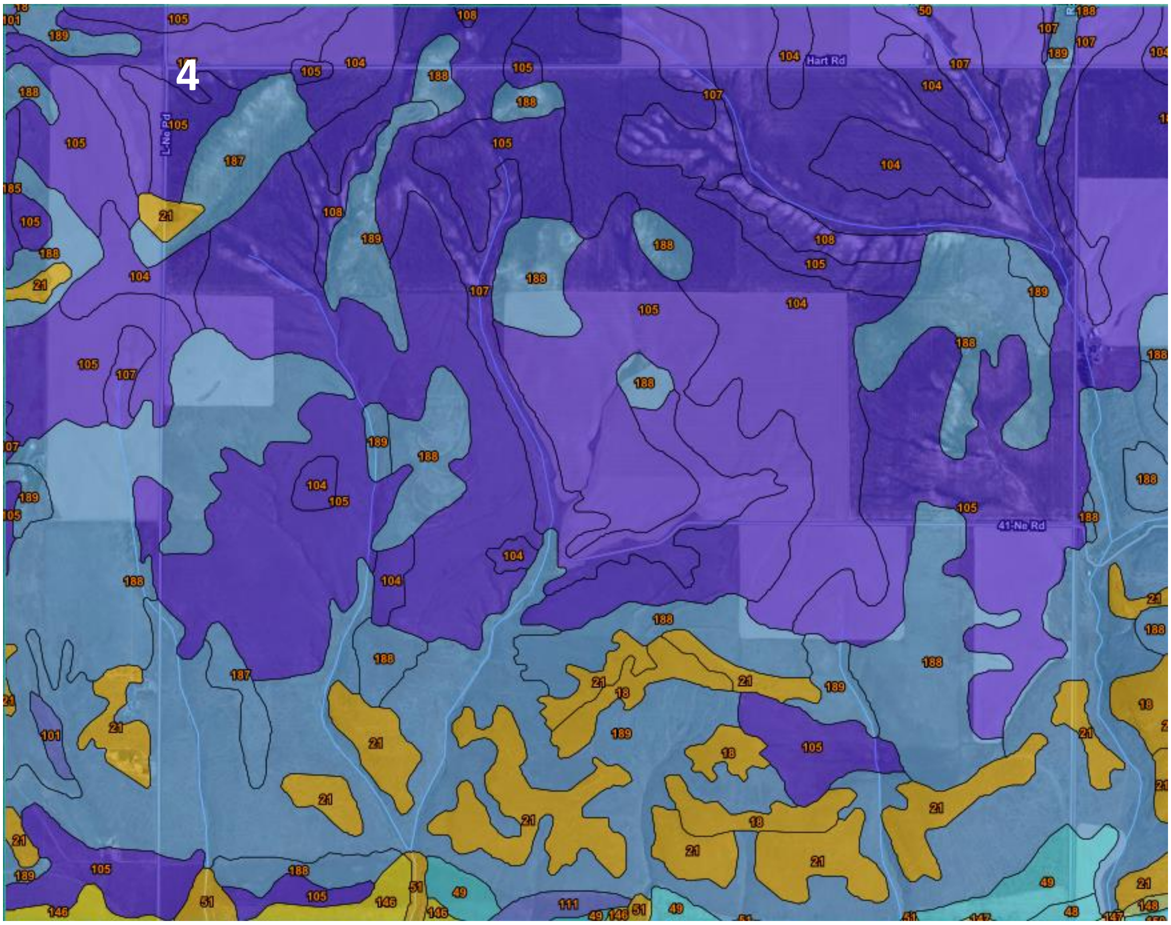


Figure 27. Rill and sheet erosion susceptibility of soils at and near Stop 4 (bold number). Soils 104 (Renslow), 105 (Renslow Association), and 107 and 108 (Renslow-Willis) all have whole soil K factors of 0.55 (purple color). This means they all are moderately susceptible to erosion. This helps explain the presence of the dendritic drainage pattern and the numerous erosion control structures. North is toward the top of the image. Source: Web Soil Survey—Properties and Qualities Ratings—Soil Erosion Factors.

Enroute to Stop 5

Road 42 NE & Road N NE Junction. Proceed east ~1.9 miles on road 42 NE through a dissected loess landscape to the junction of road 42 NE and road N NE. At the intersection, turn right (south) onto road N NE.

Road 42 NE & Road N NE Junction to Stop 5. Follow road N NE south ~1.6 miles to a vista of the Hartline Basin at GPS coordinates 47.676365°N & 119.191762°W. . Park alongside the road.

Stop 5—Mid-Slope of "Hartline Hill"

Location. We are located along road N NE for a view of the Hartline Basin.

Unnamed Canyon & Fan. Most of the route on road N NE from road 42 NE to Stop 5 occurs in an ever-enlarging, unnamed canyon (Figure 28). The canyon especially grows downstream with the addition of a tributary from the east. This canyon is eroded through the loess into the underlying basalts. A large alluvial fan lies below the mouth of the canyon (Figure 28). The alluvial fan covers part of a channel that is bounded by the eastern escarpment (Figure 28), a more subtle counterpart to the western escarpment mentioned at Stop 3. According to Bretz (1932) this abrupt margin marks the eastern extent of the Hartline Basin expansion bar. A broad, shallow channel follows this eastern escarpment (Figure 28).

Interpretations. The impressive size of the canyon and the alluvial fan at the terminus of the canyon suggests lots of geologic time or a possible Ice Age flood source for the water. Earlier, I made an argument for ample time in the creation of the "mature" landscape characterized by dendritic drainage. I stand by that statement but the canyon size here warrants something beyond time. The size, combined with the proximity of the canyon's headwaters to scabland on the eastern rim of the Upper Grand Coulee (Figure 22), suggests that floodwaters from a large Ice Age flood passing through the Upper Grand Coulee may have spilled into the Hartline Basin via this drainage (Figure 28). If so, post-flood loess has obscured the upper connection to the scabland. The presence of the large alluvial fan in the channel suggests that the fan formed after the channel was created on the edge of the Hartline Basin expansion bar. The channel lying east of the road separates the coarse expansion bar sediments from older loess. Bretz (1923, p. 74) described the channel as "*A fairly definite channel across the eastern part, leading from Grand Coulee around the northern margin and then southward to Deadman's Gulch [i.e., Arbuckle Draw].*"

Stop 5—Mouth of Unnamed Canyon

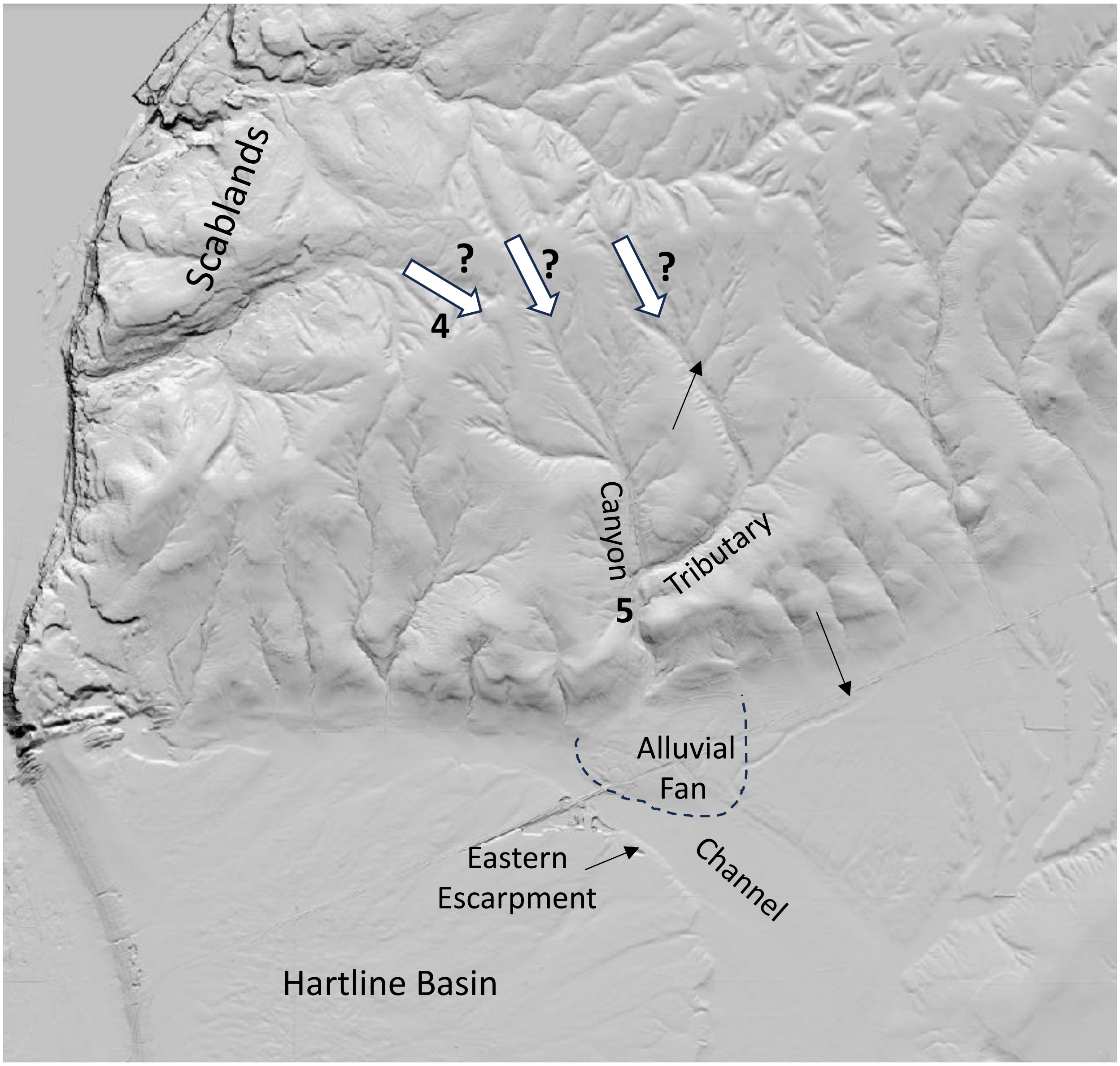


Figure 28. Dendritic drainage on uplands north of Hartline Basin (black arrow). Note the possible spillover areas for earlier Ice Age floods (white arrows). Also, note unnamed canyon, fan at mouth of unnamed canyon, eastern escarpment, and channel in vicinity of Stop 5. Bold numbers indicate approximate locations of Stops 4 & 5. Source: Washington Lidar Portal.

Enroute to Stop 6

Road N NE to Road 36 NE. From Stop 5, continue ~0.7 mile down road N NE to US 2. Cross US 2 and the railroad tracks, and continue south on road N NE for about 3.7 mile. The route crosses the eastern channel, then climbs atop and remains on the flat plain of the Hartline Basin expansion bar to near road 36 NE. Park on the side of road N NE near this junction. The approximate GPS coordinates of the junction are… 47.612453°N & 119.192082°W.

Stop 6—Hartline Basin Scablands

Location: We are located near the intersection of Road N NE and Road 36 NE in the southern Hartline Basin (Figure 29). This is very near the ~1810 ft threshold crossed by floodwaters exiting the Hartline Basin (Baker, 1973; O'Connor & others, 2020). We will walk to the southeast of this intersection onto private land that is also flood created scabland. Please do not access this land without owner permission.

Scablands & Bretz. At several of the previous stops, we have focused on depositional processes and how they have shaped the Hartline Basin. However, here, we are in a scabland area. In fact, we are in the same scabland area described by Bretz in his 1927 field notes (p, 84). He said it this way:

Hartline Basin along road straight east out of Coulee City has several striking features whose significance must not be ignored. There are scabland buttes and basins with 40 to 50 ft. of relief…A large gravel bar, with flattish tops and steep southern slopes, 30 feet high, lies south of the buttes…The basin floor thence to the gravel scarp overlooking Coulee City descends 12 feet or so to the mile toward Grand Coulee, whence came the gravel and cobbles…Nothing of which I can conceive will explain these scabland buttes and basins, this dependent bar projecting southward, this upward slope away from the channel whence came the gravel…except tremendous volume and strong current out of Grand Coulee. The debris undeniably came from that direction. It didn't come northward up Deadman's [Gulch] and it didn't come westward down the minor channel from Almira toward Deadman's Gulch. The whole thing is river bottom on a huge scale, and especially noteworthy that this was a very much broadened portion of the Grand Coulee glacial river.

Stop 6—Hartline Basin Scablands

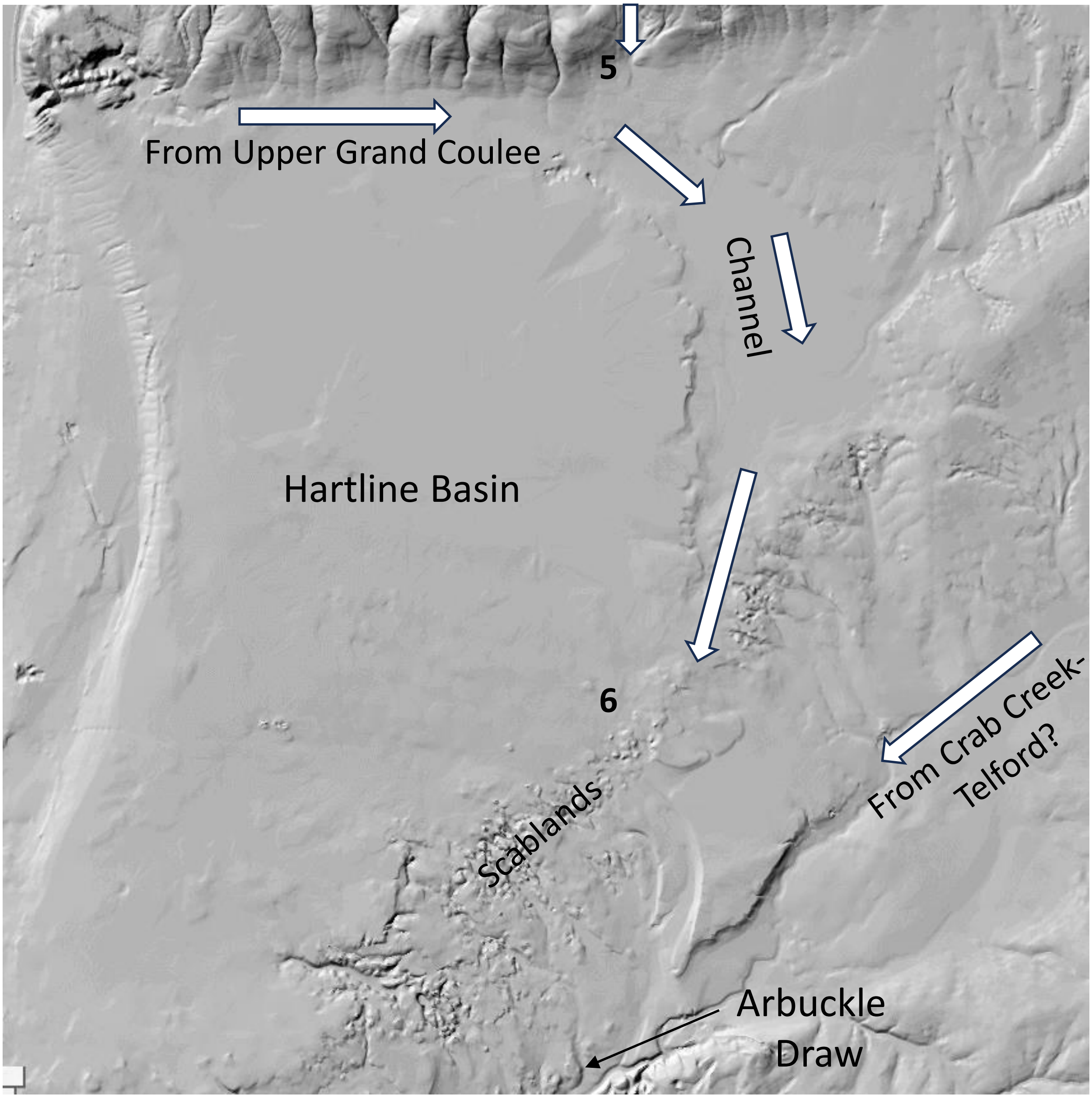


Figure 29. Stop 6 and adjacent scablands, southern Hartline Basin. White arrows indicate possible floodwater paths. Source: Caltopo.com.

Floods, Erosion & Scablands. The scablands seen here began >3 miles to the northeast and extend southwest into Arbuckle Draw and the lower Grand Coulee (Figures 29 & 30). As noted above, the source of the floodwaters that created these scablands was the Upper Grand Coulee. However, the floodwaters took an arcuate path to erode these scablands (Figure 27) creating the channel crossed between stops 5 and 6.

Stop 6—Hartline Basin Scablands

Floods, Erosion & Scablands (continued)… Further, a second, albeit small and earlier, source of water may have entered the basin from the Crab Creek Telford scabland tract east (Figures 29 & 31) (Bjornstad and Kiver, 2012). Ultimately, all floodwater entering the Hartline Basin made its way to the Quincy Basin near Soap Lake via either Arbuckle Draw or the Lower Grand Coulee (Figure 30).

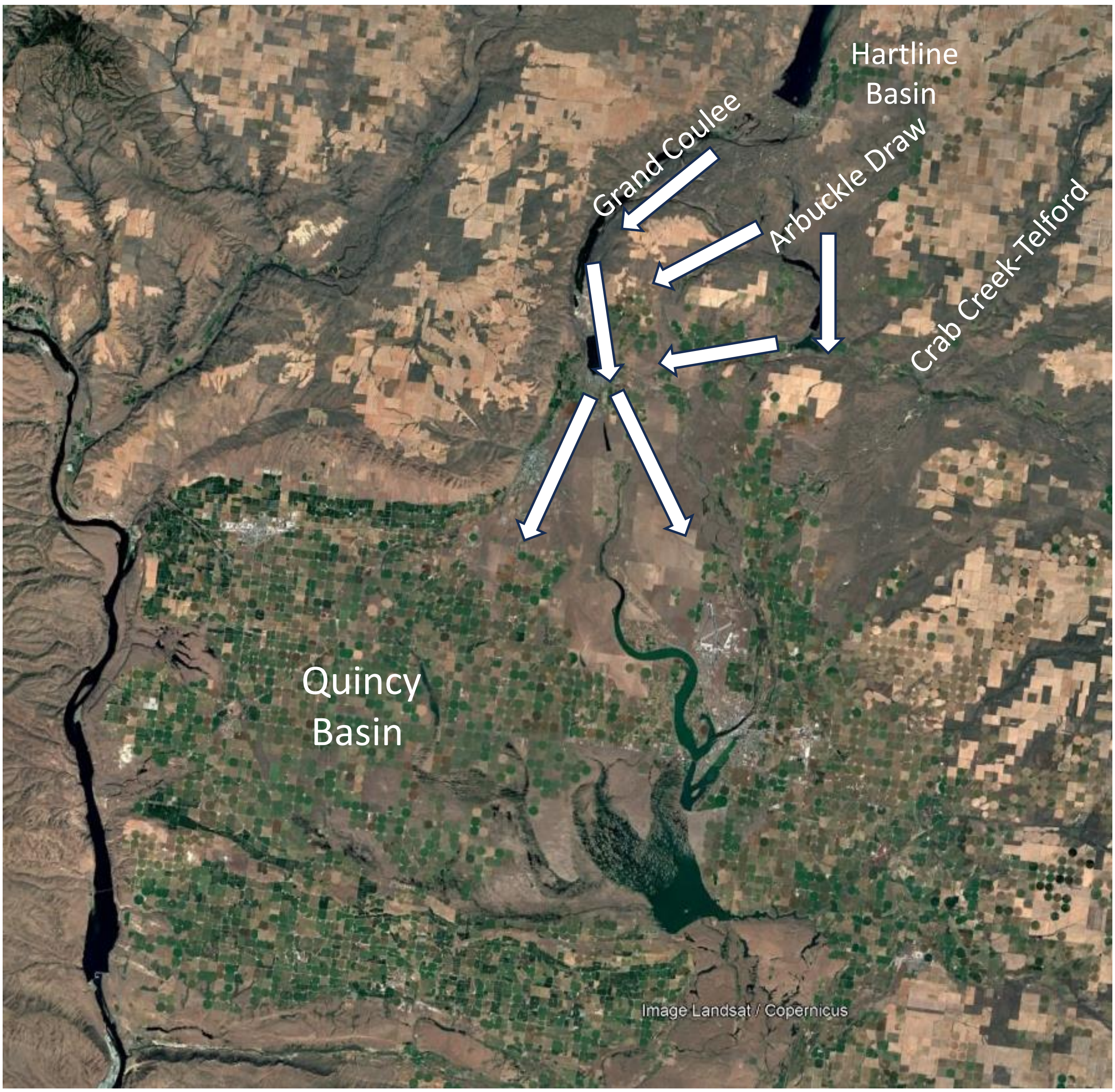


Figure 30. Flood pathways (white arrows) from the Hartline Basin southward to the Quincy Basin. North is toward top of image. Source: Google Earth Pro, 2/25/2024.

Stop 6—Hartline Basin Scablands

Floods, Erosion & Scablands (continued**)**. The basalts here are eroded into a confusing array of channels, closed basins, and steep-sided buttes (Figures 32 & 33). These features are characteristic of the "channeled scablands". Scabland has long been a very descriptive term for this harsh landscape. Bretz (1923) added "channeled" to scabland to emphasize the preponderance of channels within these scablands. Ice Age floods eroded the landscape by abrasion, direct hydraulic action, cavitation (i.e., implosion of gas bubbles) and the action of large, rapidly rotating, vertical vortices (like an underwater tornado) known as "kolks". These vortices "plucked" basalts (especially columns of the colonnades) (Figures 34 & 35) from the exposed basalt flows creating deep, steep sided "potholes".

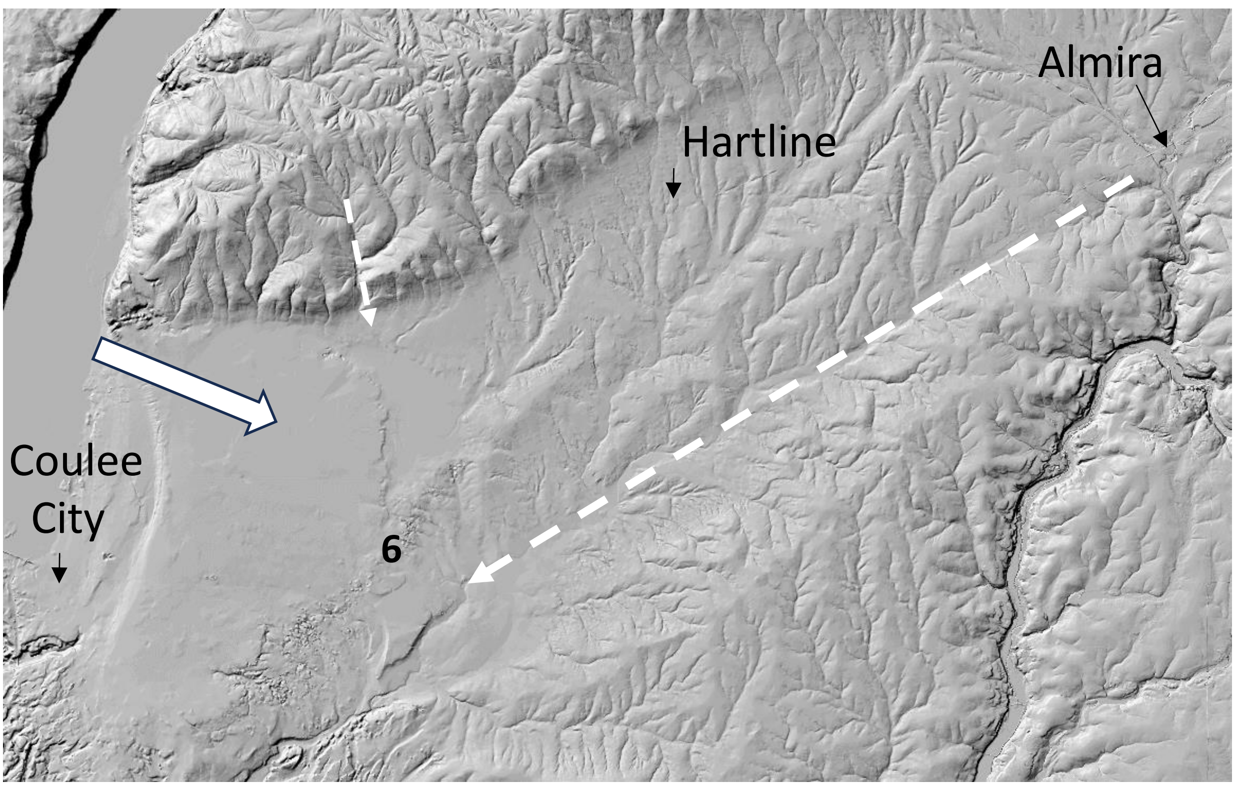


Figure 31. Probable (solid arrow) and possible (dashed arrows) routes of water into the Hartline Basin. Bold number is Stop 6. Source: Caltopo.com

Stop 6—Hartline Basin Scablands

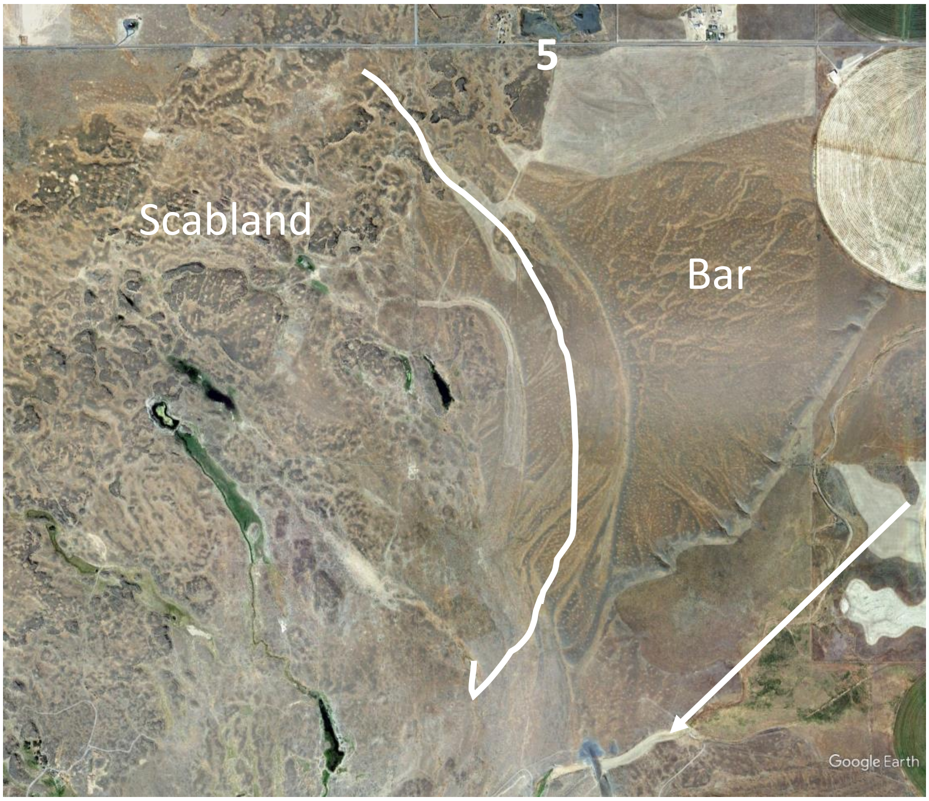


Figure 32. Scablands and giant pendant flood bar at Stop 5. General flood flow direction indicated with arrows. North is toward top of image. Source: Google Earth Pro, 9/13/2011

Figure 33. Ground view of butte & basin topography in the Hartline Basin scablands. Source: Author photo, 13 April 2025

Stop 6—Hartline Basin Scablands

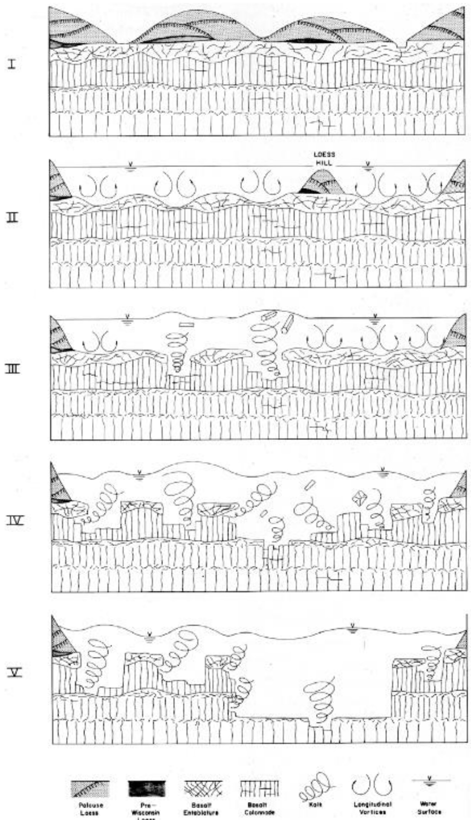


Figure 34. Illustration of kolk-based erosion in columnar jointed basalts. Source: Baker & others (2016, p. 34).

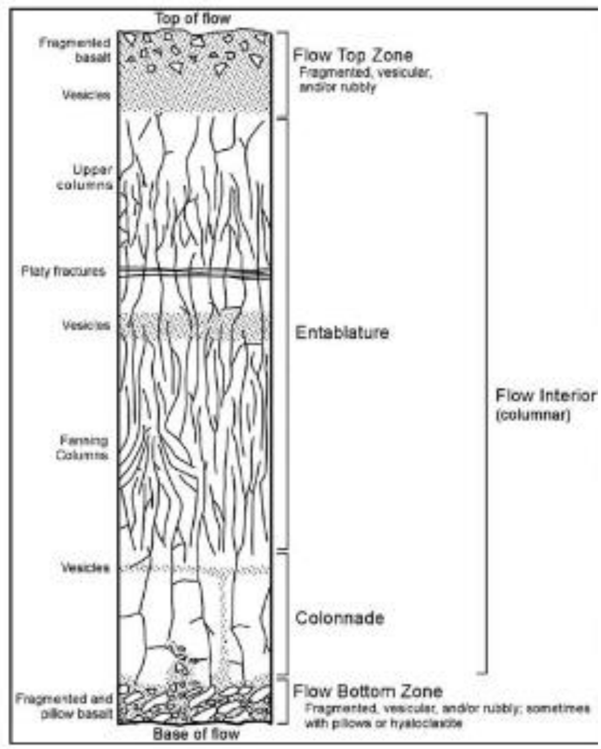


Figure 35. Typical Columbia River Basalt flow cross-section. Source: **Baker & others (2016, p. 5).**

Scablands & Giant Bars. Giant bars are relatively common in scabland tracts. Therefore, the giant bar here should not come as a surprise. However, the size of the bar may impress you—it is least 2 miles long and nearly 1.5 miles wide at its widest point (Figure 32)! It is a pendant bar formed in the lee of slightly higher scablands to the north (Figure 29). So how does a depositional feature that depends on lower velocities form in an area characterized by erosion and high velocities? Like real estate, the answer is location-location-location! Different parts of channels have different velocities. Typically, the highest velocities are in the deep, central parts of channels while the lowest are found on the shallow margins. Pendant bars forms in the lee of obstructions where velocities are lower, and where deposition can readily occur.

Wrapping Up

Today, we have travelled from the Upper Grand Coulee eastward to see homoclines of the Coulee Monocline, gravels of the Hartline Basin, soils above the flooding on the "Hartline Hill", a possible flood route through the "Hartline Hill", and finally scablands in the southern Hartline Basin. Enroute, we have explored issues tied to contemporary agriculture in the area.

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 or (509) 963 1184 if you have further questions/comments. I hope to see you on the next trip in spring 2026.

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