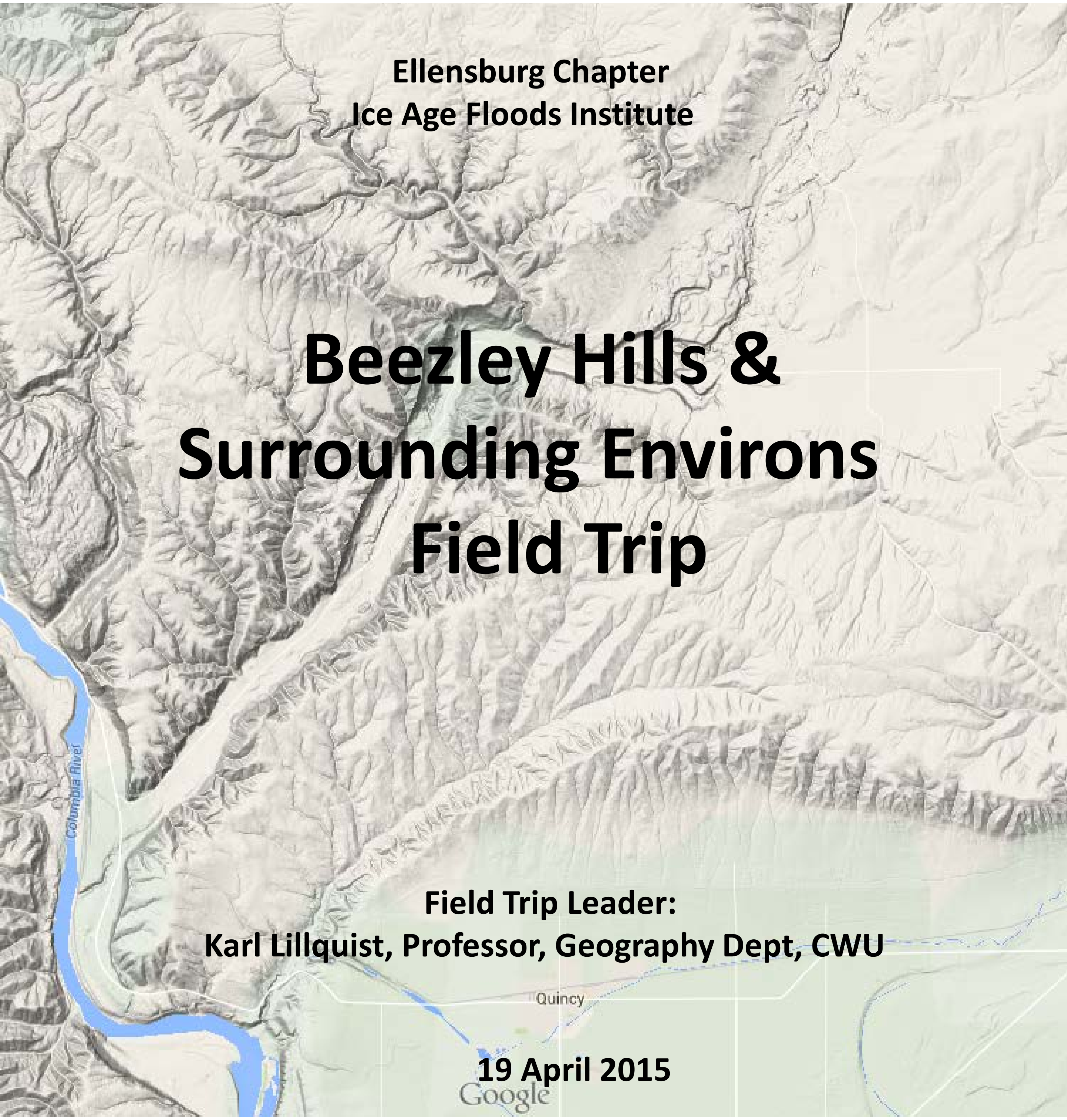


Ellensburg Chapter
Ice Age Floods Institute

Beezley Hills & Surrounding Environs Field Trip

Field Trip Leader:
Karl Lillquist, Professor, Geography Dept, CWU

19 April 2015

Preliminaries

Field Trip Overview

The Beezley Hills form the southern extent of the Waterville Plateau and the northern border of the Quincy Basin. In the late Pleistocene, these hills lay between the Okanogan Lobe of the Cordilleran Icesheet and the massive Missoula Floods that shaped the Quincy Basin. However, the icesheet stopped ~25 miles north and floods only scoured the lower, south slopes of the hills leaving the higher elevations relatively unscathed. Much of our day will focus on sites above the level of ice age flooding. Topics here will include: interpretation of thick loess deposits and associated soils that likely pre- and post-date the last of the ice age floods; partial erosion of the loess blanket leaving mounded topography; deposition of Mazama ash in moist valley bottom sediments; and historic incision into these sediments forming an impressive arroyo. A later stop will focus on ice age floodwaters exiting the northwestern part of the Quincy Basin to form Crater Coulee. Our final stop will be an overview of West Bar on the Columbia River near Trinidad.

Tentative Schedule

10:00 am	**Depart CWU**
11:00	**Stop 1—East Park, Quincy**
11:15	**Depart**
11:30	**Stop 2—Monument Hill**
12:15	**Depart**
12:30	**Stop 3—Upper Lynch Coulee**
1:15	**Depart**
1:30	**Stop 4—Baird Springs (Middle Lynch Coulee)**
2:15	**Depart**
2:30	**Stop 5—Crater Coulee (Lower Lynch Coulee)**
3:15	**Depart**
3:30	**Stop 6—West Bar Overlook**
4:15	**Depart**
4:30	**Stop 7—Quincy Valley Rest Area**
4:45	**Depart**
6:00	**Arrive at CWU**

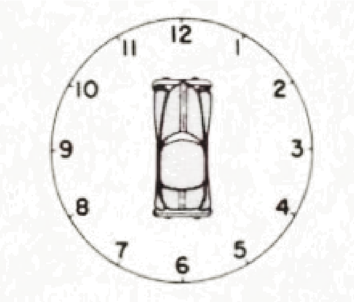


Figure 1. Relative bearings using a clock. Assume that the bus is always pointed to 12 o'clock. Source: Campbell (1975, p. 1).

Our Route & Stops

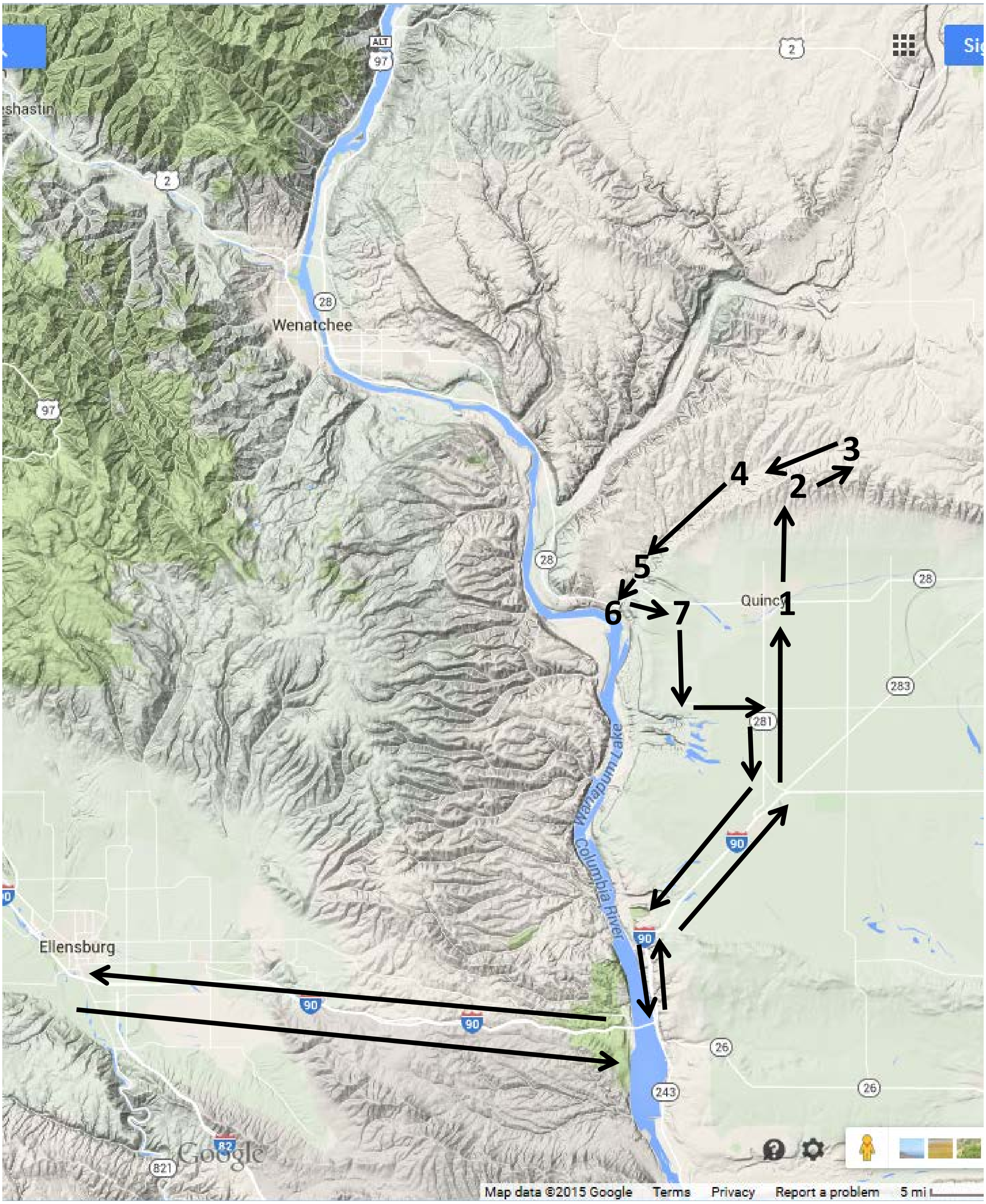


Figure 2. Route map for field trip. Approximate locations of stops shown with numbers. Source: Google maps.

Ellensburg to East Park (Quincy)

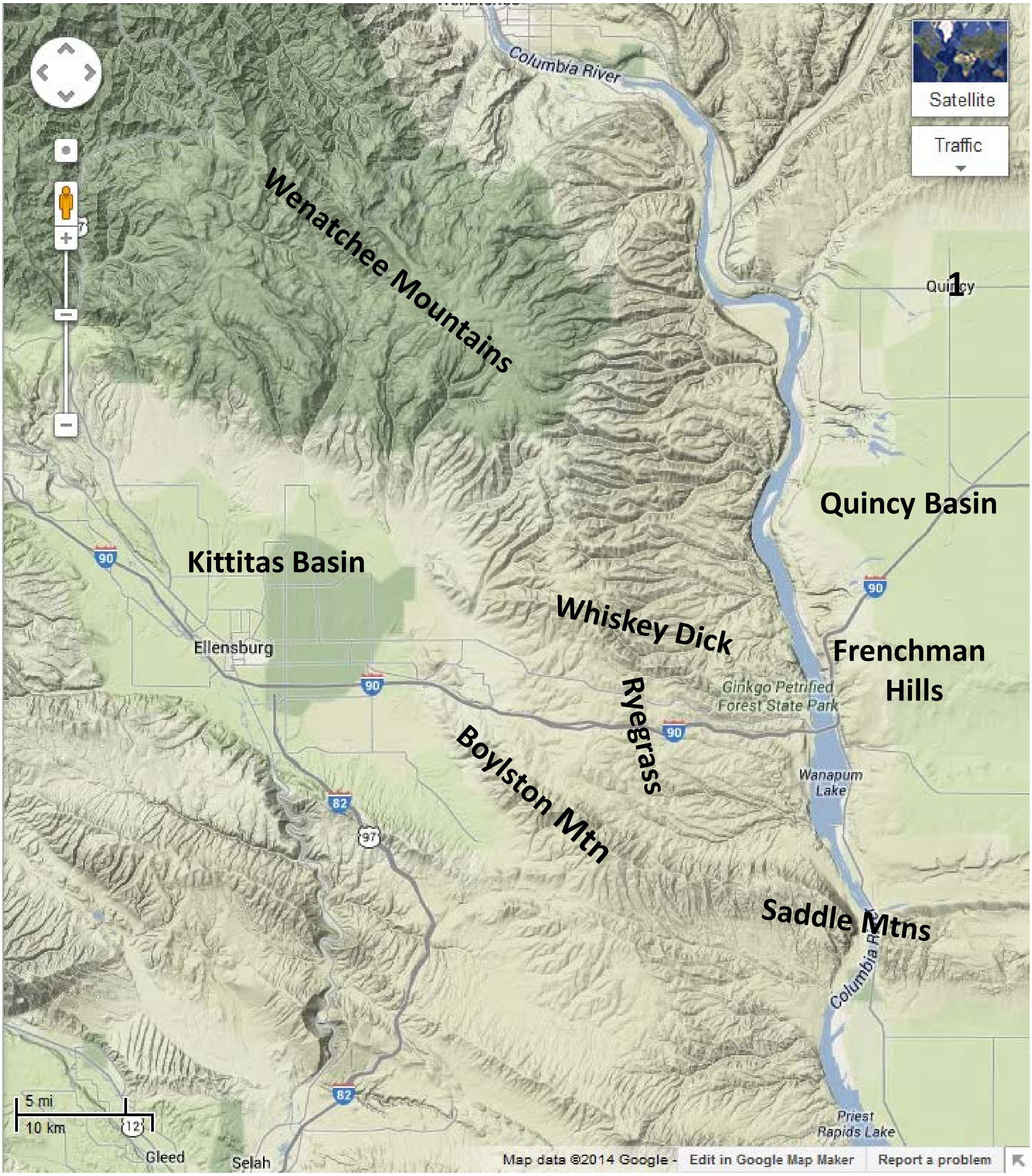


Figure 3. Topography of Ellensburg to Quincy's East Park in the Quincy Basin part of our route. Source: Google Maps.

Ellensburg to East Park (Quincy)

Route: Our route to Stop 1 takes us from Ellensburg to Quincy's East Park in the Quincy Basin via I-90, WA 281, and WA 28 (Figures 2 & 3). We enter the Quincy Basin essentially where I-90 reaches its high point before descending to the Silica Road exit. We continue east on 1-90 from the Silica Road Exit to George. Take Exit 149 at George, and head north on WA 281 to Quincy. At the junction of WA 281 and WA 28 in downtown Quincy, head east on WA 28. Near the east end of town (just south of John Deere/Washington Tractor), turn south (left) into East Park. This is Stop 1.

Kittitas Basin Lithology & Structure: Ellensburg lies near the western margins of the Columbia River Basalts. Our drive from Ellensburg begins on the floor of the Kittitas Basin syncline with downfolded Columbia River Basalts ~4000 feet below us (Figures 4, 5, 6 & 7). Mantling the Columbia River Basalts are volcanic sediments of the Ellensburg Formation, alluvial fan sediments from the surrounding mountains , Yakima River alluvium, and loess. East of Kittitas we ascend the upfolded Ryegrass anticline (Figure 7).

Kittitas Basin Climate: The wind towers of the Wildhorse and Vantage Wind Farm remind us of the regularity and strength of winds on the eastern margins of the basin. The thick, fine textured deposits of loess that blanket the Badger Pocket area in the southeastern part of the Kittitas Basin are a reminder of the importance of wind over time as well.

Missoula Floods: Descending the Ryegrass anticline, we reach the upper limit of Missoula Flood slackwater at ~1260 feet (Figure 8) between mileposts 133-134. Look for changes in the shrub steppe vegetation as well as thick gravel deposits to indicate that we have crossed into the area once inundated by floodwaters. Also, keep your eyes peeled for light-colored, out-of-place rocks atop the basalts in this area—these are iceberg-rafted dropstones (also called erratics) deposited by the floods. As we descend to Vantage at ~600 feet elevation on the Columbia River, recognize that floodwaters lay ~600 feet over our heads at their deepest extents. The Columbia River "Gorge" here is a result of pre-Missoula Flood, Missoula Flood, and post-Missoula Flood erosion. East of the Columbia River, the ~horizontal bench we follow until nearly entering the Quincy Basin and the Columbia Basin Irrigation Project is a stripped structural surface created by selective erosion of Columbia River Basalts to the level of the Vantage sandsone. Several landslides are visible atop the Vantage sandstone in the slopes to the right (east) of our bus. From here, we also have fine views of Channeled Scablands (to your west) that are so indicative of Missoula Flood-ravaged surfaces.

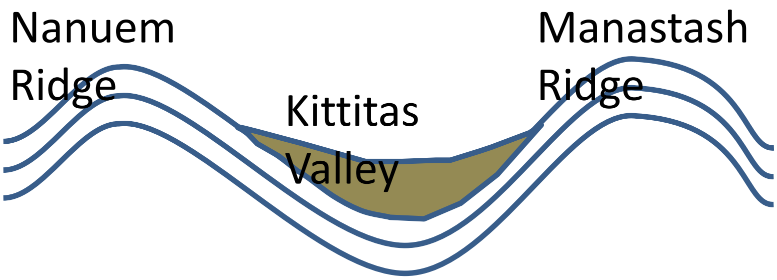


Figure 4. Location of Kittitas Basin syncline between Naneum Ridge and Manastash Ridge anticlines. Source: Jack Powell.

Ellensburg to East Park (Quincy)

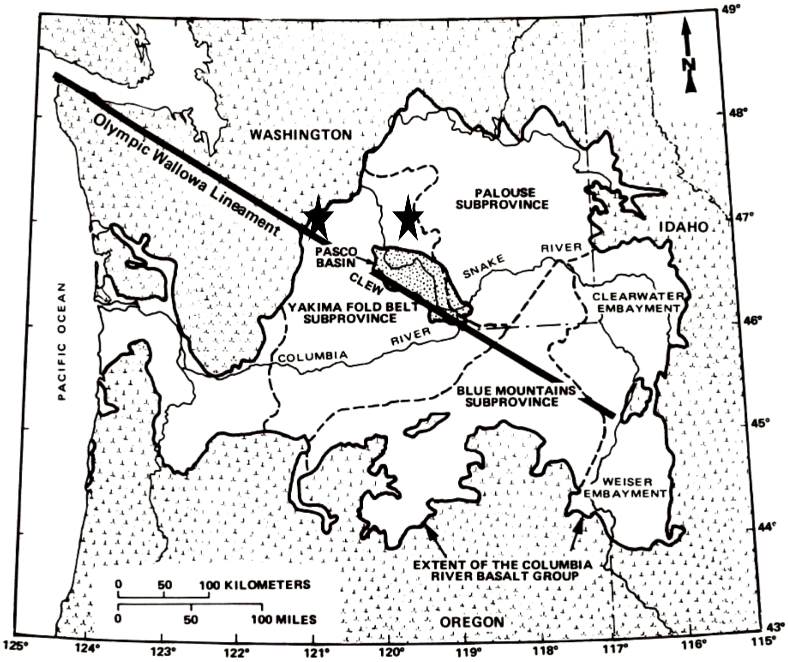
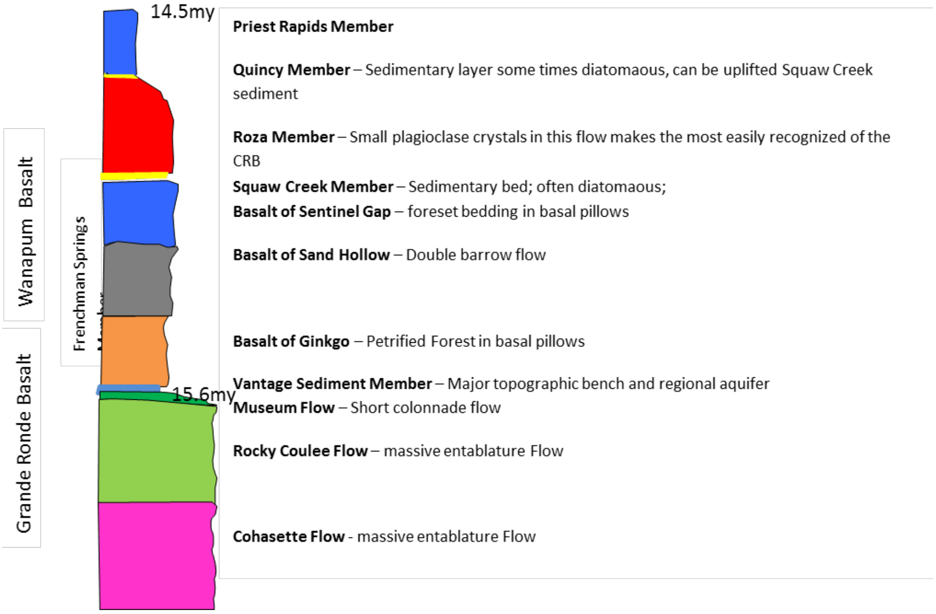


Figure 5. The Columbia Plateau and the areal extent of the Columbia River Basalt Group, the four major structural-tectonic subprovinces (the Yakima Fold Belt, Palouse, Blue Mountains, and Clearwater-Weiser embayments), the Pasco Basin, the Olympic-Wallowa lineament. Stars indicate approximate locations of Ellensburg and the Beezley Hills. Source: Reidel & Campbell (1989, p. 281).



Priest Rapids Member

Quincy Member – Sedimentary layer some times diatomaous, can be uplifted Squaw Creek sediment

Roza Member – Small plagioclase crystals in this flow makes the most easily recognized of the CRB

Squaw Creek Member – Sedimentary bed; often diatomaous;

Basalt of Sentinel Gap – foreset bedding in basal pillows

Basalt of Sand Hollow – Double barrow flow

Basalt of Ginkgo – Petrified Forest in basal pillows

Vantage Sediment Member – Major topographic bench and regional aquifer

Museum Flow – Short colonnade flow

Rocky Coulee Flow – massive entablature Flow

Cohasette Flow - massive entablature Flow

Figure 6. Stratigraphy of the Columbia River Basalt Group. Source: Jack Powell.

Ellensburg to East Park (Quincy)

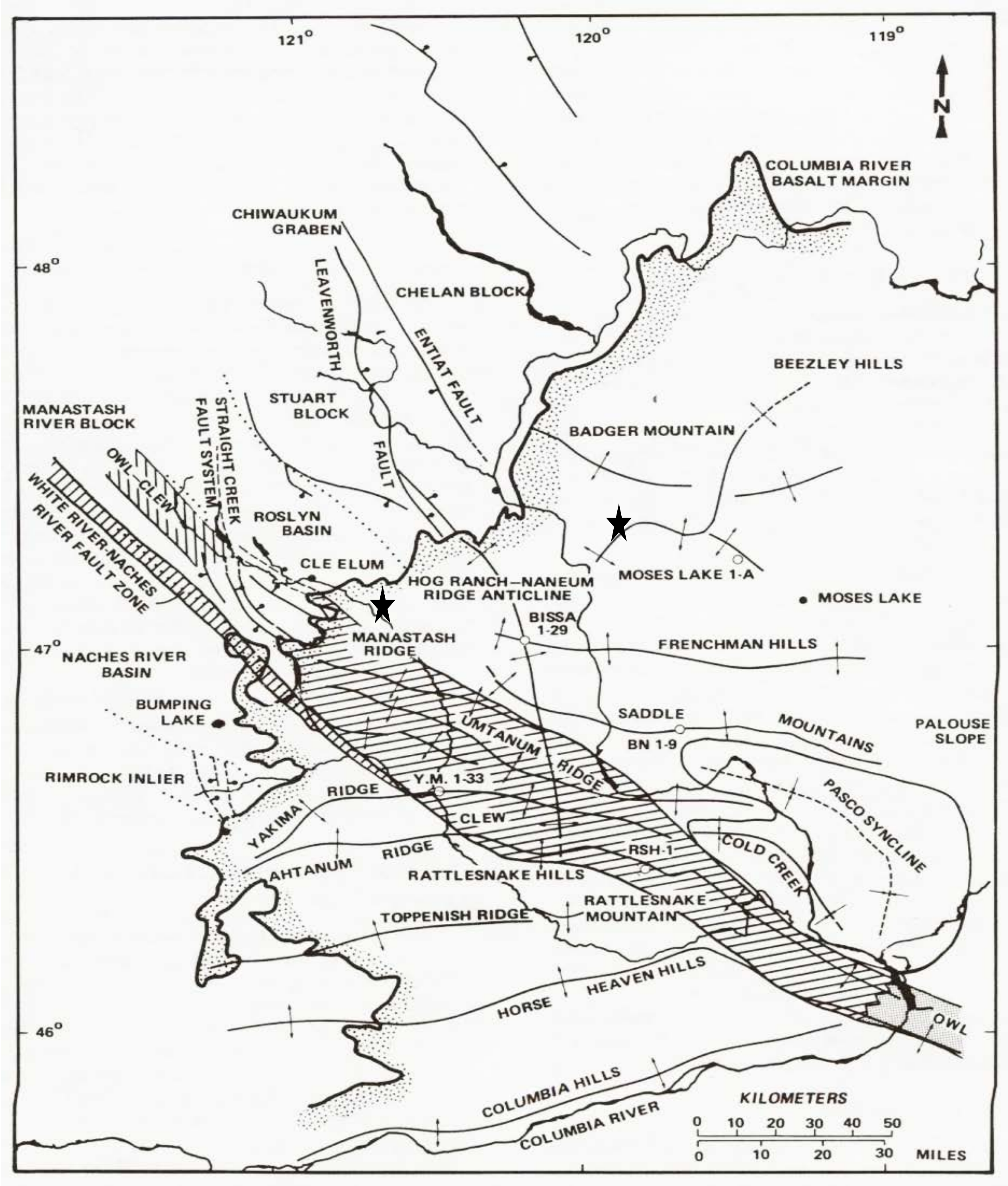
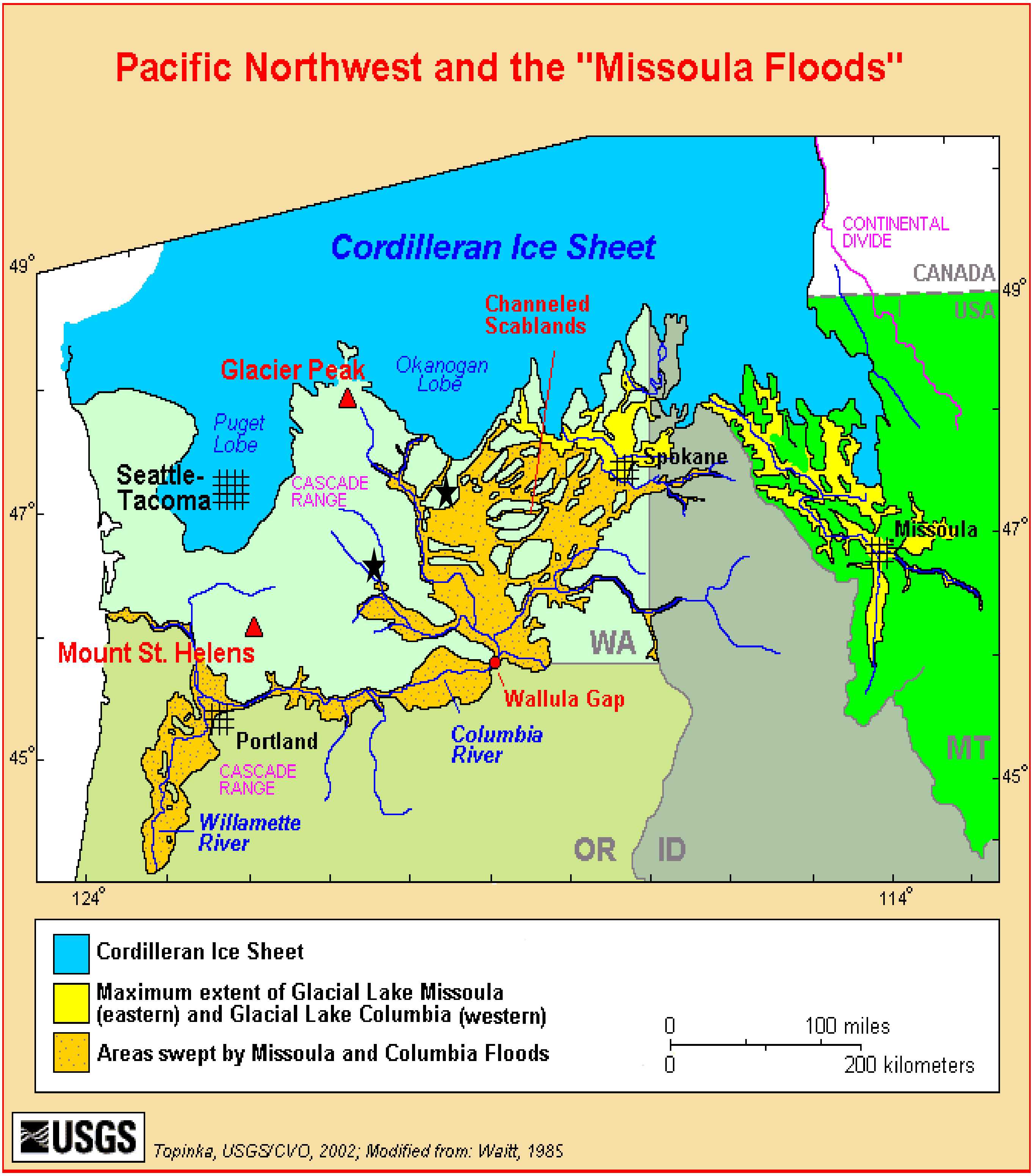


Figure 7. Generalized map of major faults and folds along the western margin of the Columbia Plateau and Yakima Fold Belt. Stars indicate locations of Ellensburg and Monument Hill in the Beezley Hills. Source: Reidel & Campbell (1989, p. 281).

Ellensburg to East Park (Quincy)



Topinka, USGS/CVO, 2002; Modified from: Waitt, 1985

Figure 8. Map of the late Pleistocene Cordilleran Icesheet and Missoula Floods in the Pacific Northwest. Stars indicate approximate locations of Ellensburg and the Beezley Hills. Source: Cascade Volcano Observatory website.

Quincy Basin

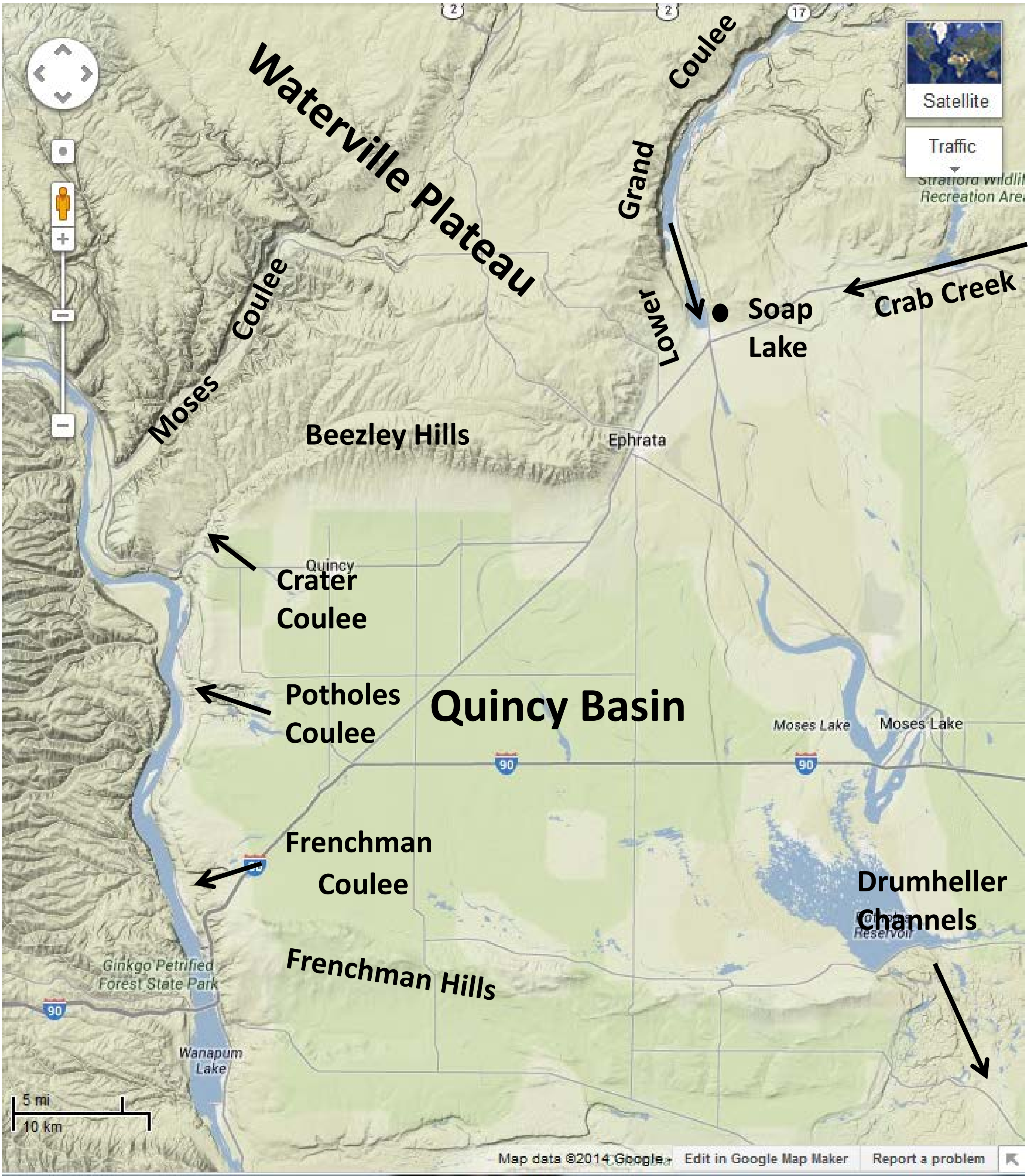


Figure 9. Topography and significant features of the Quincy Basin. Arrows show direction of flood flows into, and out of, the Quincy Basin. Source of image: Google Maps.

Ellensburg to East Park (Quincy)

Quincy Basin Substrate: The Quincy Basin is underlain by Miocene Grande Ronde and Wanapum basalts of the Columbia River Basalt group (Figures 5 and 6). The individual flows are interbedded with sedimentary units including diatomaceous earth, which is mined in the basin. The Ringold Formation, a mix of Tertiary and Quaternary alluvial and lacustrine sediments, is found in scattered exposures in the basin. Gravels, sands, and silts associated with late Quaternary Missoula Floods cover much of the basin. Loess mantles much of the surrounding slopes of the basin (Figure 10). The tan soils of the basin are low in organic matter and indicate aridity.

Quincy Basin Area Geologic Structure: The Frenchman Hills and Beezley Hills (Figure 9) are anticlines on the northwestern part of the Yakima Fold and Thrust Belt (Figure 7) that bound the southern and northern margins of the Quincy Basin. These anticlines guided floodwaters entering the basin from the northeast and east.

Quincy Basin Cover Sand and Topography: Windblown sand originating from the Columbia River and from wind reworking of distal Missoula Flood deposits covers much of the basin floor. Unlike the deposits near Moses Lake, these deposits take on the flatter form of cover sand rather than dunes, perhaps reflecting the lower amount of sand available. These sands are a main parent material for the basin's soils. Where measureable relief exists in the western Quincy Basin, it is often shaped by underlying Missoula Flood erosional or depositional forms. This is especially true of the final three miles leading northward into Quincy where WA 281 loses elevation and crosses the subtle head of the channel leading to Crater Coulee (see Stop 5).

Quincy Basin Climate: Quincy's climate is somewhat warmer and drier than that of Ellensburg. Mean annual temperatures here nearly 3^{o}F warmer despite being only 200 feet lower than Ellensburg (Figure 10). Quincy also receives nearly 1 inch less precipitation than Ellensburg likely because of increased distance from the Cascade Range. Wind data is scarce for most Washington climate sites and Quincy is no exception. Based on wind data for Ephrata and Moses Lake, it is likely that Quincy's dominant winds are from the west but its unclear whether they are more like Ephrata (northwest) or Moses Lake (southwest). Wind direction is an important variable that we will discuss at Stop 3.

Quincy: Quincy originated in 1902 along the Great Northern Railroad (Meinig, 1968). Its history has long been tied to agriculture. Writers for the Works Project Administration wrote in 1941 "*This part of the Columbia Basin is both a land of promise and a graveyard of hope. Despite the lightness of precipitation, which is seldom more than six inches annually, there are productive farms and flourishing stock ranches on the deep soil, rich in nitrates, lime, and magnesium. Scattered along the highway are ghost farms with their deserted houses, weather-beaten barns, and uprooted skeletons of fruit trees, a tragic residue left by settlers, who, at the turn of the century, hopefully broke the land and waited for the promised irrigation to materialize. The dream which they dreamed too soon is now about to become a reality* (p. 330).

Columbia Basin Irrigation Project: The Quincy Basin is a vastly different place now than in 1941. Prior to that time, it was a dry, sand-covered basin characterized by ranching and meager attempts at dryland and small scale irrigated farming. Columbia River water was first delivered to the area from Lake Roosevelt (behind Grand Coulee Dam) via Banks Lake and a series of canals and siphons in 1952. Now the Columbia Basin Irrigation Project boasts over 60 different crops.

Stop 1—East Park (Quincy)

Location: We are located in Quincy's East Park.

Restrooms: This is our only official bathroom stop until late this afternoon. We will also use this as a meeting place for field trippers joining us from the Wenatchee and Moses Lake areas.

East Park (Quincy) to Monument Hill

Route: Immediately upon returning to the eastbound lane of WA 28, turn north (left) onto Columbia Way. Follow this road as it winds noth through light industrial Quincy. Note the huge cold storage facilities and computer server farms to our east, and the steam from the diatomaceous earth processing plant to our west. Columbia Way soon becomes road P NW. Follow this north to the end of the pavement and beyond as a good gravel road to Monument Hill atop the Beezley Hills. Park on the right shoulder of this gravel road and walk to the top of Monument Hill. Monument Hill is recognizable as the highest point on the Beezley Hills and is the home of numerous cell towers.
High Flood Level: According to Bjornstad (2006) ice age floodwaters reached an elevation of at least 1,425 feet in the Quincy Basin. We cross this elevation before leaving the irrigated lands north of Quincy. Above this elevation, we are on non-flood impacted surfaces.

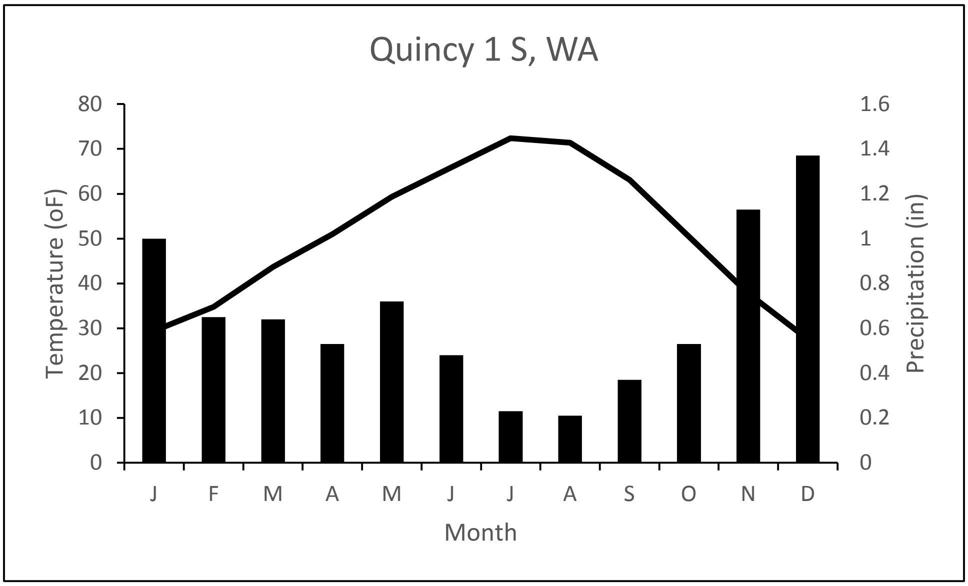


Figure 10. Climate data for Quincy 1 S site, 1981-2000. Source: Western Regional Climate Center (n.d.).

Stop 2—Monument Hill

Location: We are located at 2882 feet on Monument Hill which sits atop the Beezley Hills. On a clear day, a great view is had in all four cardinal directions.

Geology of the Beezley Hills: The Beezley Hills are composed of Miocene-aged Grand Ronde basalts of the Columbia River Basalt Group (Figures 5 & 6). These basalts have been up-folded but are more complex than a simple anticline. Of the four structures mapped in the Beezley Hills, three are either anticlines or monoclines (one fold) (Figure 11). Lynch Coulee to our north occupies a syncline. We are located near the north end of the Yakima Fold and Thrust Belt (Figure 7).

Mountains to the West and Northwest: The eastern sides of the Wenatchee Mountains, Stuart Range, and Chiwaukum Mountains are visible from here on a clear day. The Wenatchee Mountains are composed of folded Tertiary sedimentary rocks, Columbia River Basalts, and associated interbeds. Jurassic granitics comprise the Mt. Stuart batholith while the Chiwaukum Mountains are late Cretaceous intrusive igneous and metamorphic rocks (Tabor and others, 1982; Tabor and others, 1987). Further north, we see the mountains reflecting the varied geology of the North Cascades. The forested nature of these ranges, and typical April snowcover reminds us of the steep climate gradient from the Cascade Range to the Columbia Plateau.

Okanogan Lobe to the North: Were we to have stood here ~15,000 years ago and looked ~25 miles north, we likely would have seen the terminus of the Okanogan Lobe of the Cordilleran Icesheet towering ~3000 feet over the landscape (Waitt and Thorsen, 1983) (Figure 12). While the Okanogan Lobe did not cover our site, it likely influenced this area. Cold, dry winds originated over the lobe and probably blew toward the lowlands to the south creating a periglacial (i.e., near-glacial) climate characterized by permafrost and intensive freezing and thawing. They may have also deflated (i.e., picked up) and entrained fine sediments to later be deposited downwind.

"Wild West" to the North & East: The "Wild West" of the area to the north and east is seen in the wide open spaces and limited imprint of humans. Much of the land use in view is rangeland, and it was likely the first Euroamerican land use to shape the area in the late 1800's. Dryland agriculture followed ranching to the area. The dryland agriculture seen here is a summer fallow system where a particular piece of land grows grain (typically wheat) one year and lies fallow the next to collect moisture. Because of steep slopes (hence high erodibility) and marginal yields in this dry setting, much land that was once farmland has been placed into the Conservation Reserve Program beginning in the mid-1980's. These lands now support a grassland-dominated shrub steppe and are again rangeland or preserved as conservation lands (see below).

Quincy Basin & Ice Age Floods: From the top of Monument Hill, our view to the southeast, south and southwest is focused on the Quincy Basin. The Quincy Basin has long been a key part of the Missoula Flood story. Floodwaters entered the northeastern portion of the basin from the Lower Grand Coulee and Crab Creek. These floodwaters built a huge expansion bar (like an alluvial fan but constructed <u>beneath</u> the floodwater) that extended across much of the Quincy Basin. Floodwaters exited the Quincy Basin in two main areas—Drumheller Channels to our southeast (just beyond Potholes Reservoir) and several outlets to the southwest of us—Frenchman Springs Coulee, Potholes Coulee, and Crater Coulee. Floodwaters were guided to the western part of the Quincy Basin by the Beezley Hills and the Frenchman Hills. Crater Coulee will be the focus of Stop 5.

Stop 2—Monument Hill

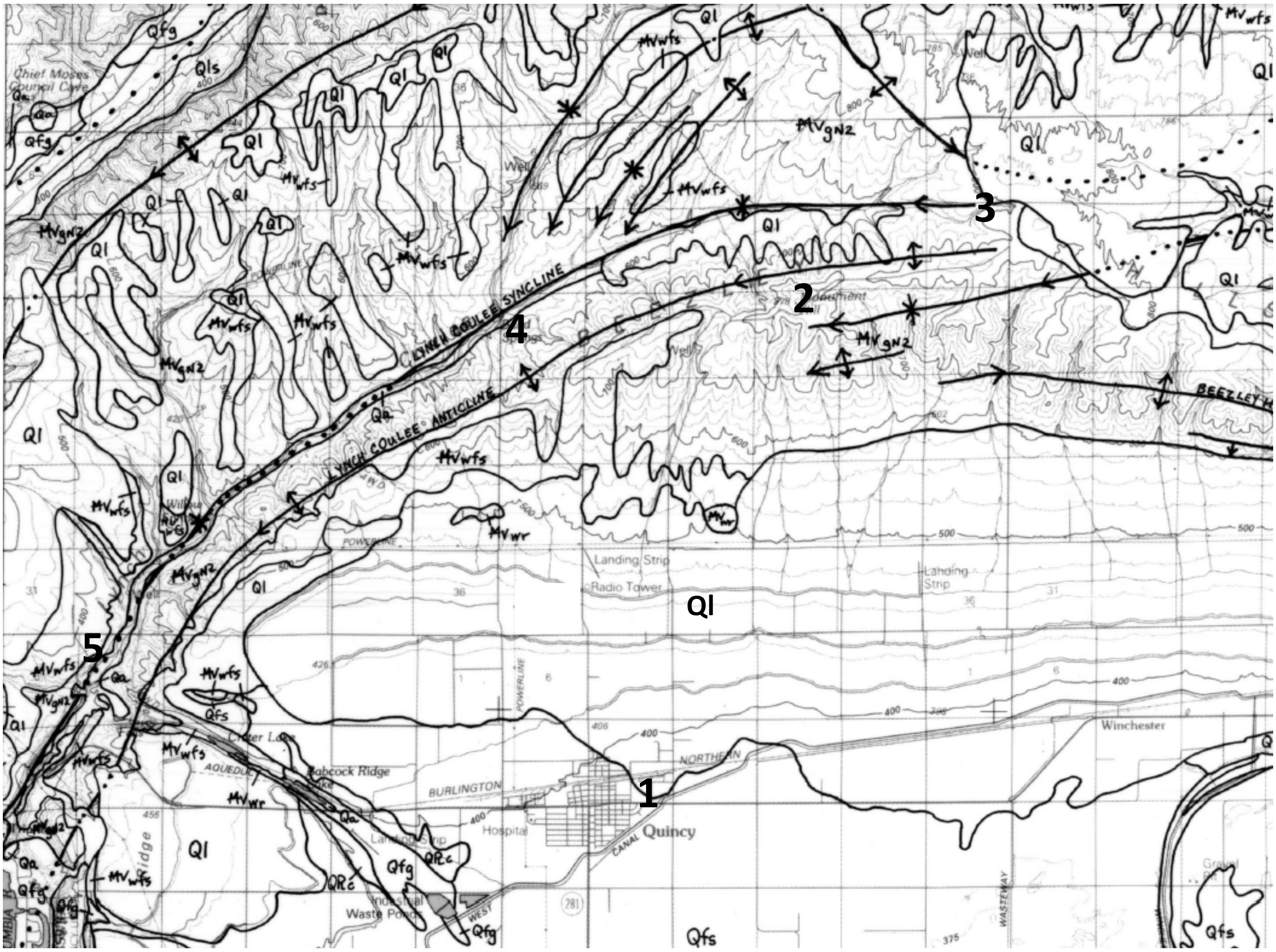


Figure 11. Geology of the Beezley Hills area. Note the locations of numbered stops. Also, note the anticlinal (arrows diverging) and synclines (arrows converging) indicating the structural origin of the Beezley Hills. Source: Gulick (1990).

Stop 2—Monument Hill

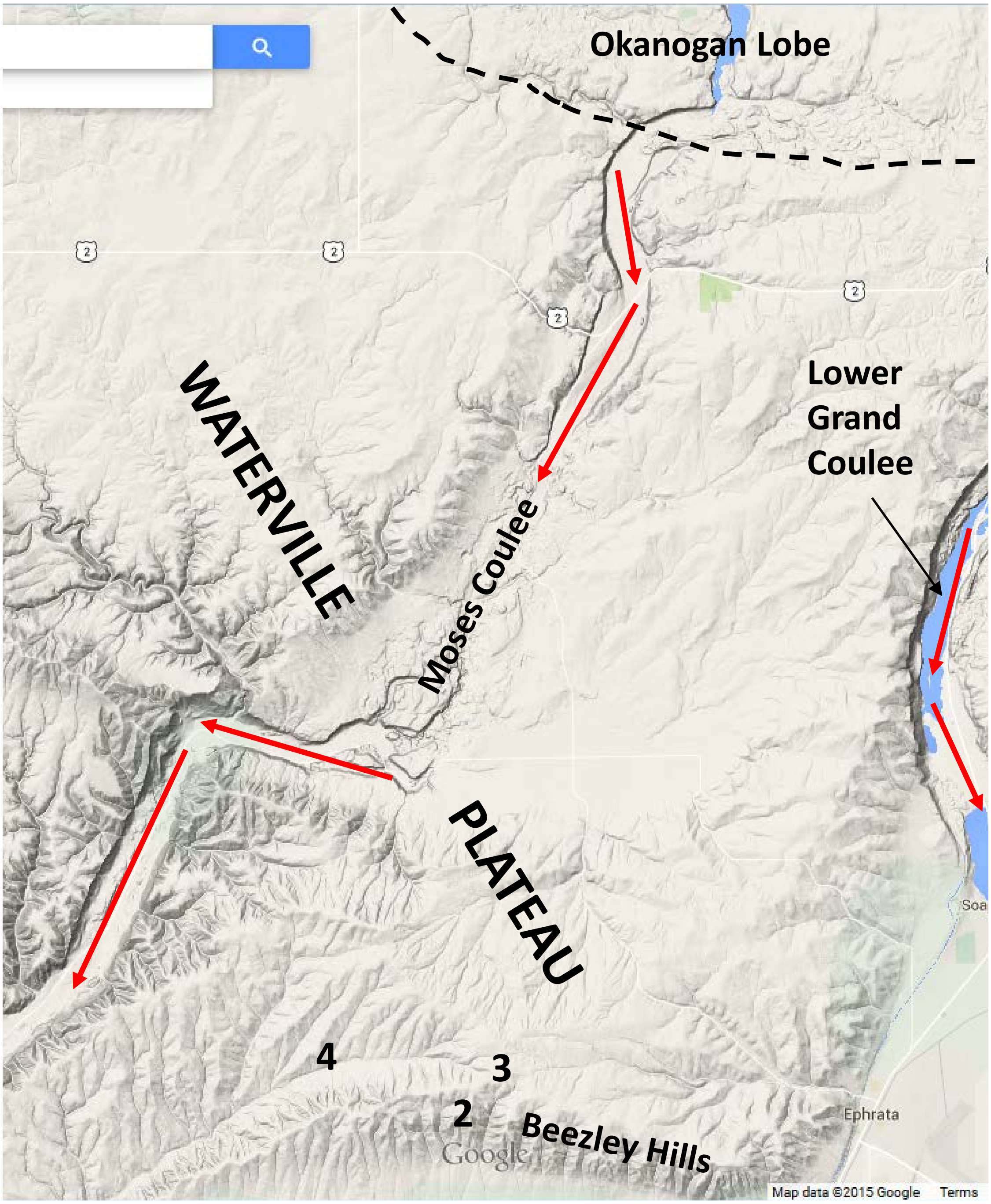


Figure 12. Landscape to north of Monument Hill and the Beezley Hills. Southern limit of late Pleistocene Okanogan Lobe of the Cordilleran Icesheet shown with dashed line. Pre-late Pleistocene Moses Coulee and late Pleistocene Grand Coulee path of ice age floods shown with arrows. Numbers represent field stops. Source: Google Maps.

Stop 2—Monument Hill

Eroded Beezley Hills: A glance at Figure 13 reveals that the Beezley Hills shows ample evidence of stream erosion despite the semi-arid nature of the climate here. Deep channels are incised on both sides of the ridge seen in Figure 13 but are larger (i.e., deeper and wider) on the south side of the Beezley Hills. I suspect that this reflects initially steeper terrain on the south- facing slope that resulted from compression creating the series of anticlines, synclines, and monoclines that make up the geologic structures of the area. Perhaps the result of the compression was an asymmetrical anticline with a steeper south face than its north face.

Lithosols: Much of this hilltop is covered by lithosols which are shallow, rocky soils with poorly define horizons (i.e., layers). I assume that this surface was once covered by thick deposits of loess like we will see at the base of this hill and at Stop 3. Water and wind have eroded much of the loess leaving a lithosol behind. In places, the lithosol is so eroded that a stone layer (i.e., desert pavement) covers a heterogenous mix of clay, silt, sand, and coarser sediments.

Patterned Ground: Patterned ground appears as pimple-like features scattered about on the lithosols of the Beezley Hills (Figure 14). This patterned ground appears to differ from that seen around the margins of the Kittitas Basin in that it lacks rings of sorted stones. Are the mounds erosional remnants of a once-continuous loess blanket? Are they periglacial phenomena formed in the late Pleistocene? Or did they form from seismic activity or burrowing rodents? You will see many examples of these mounds between Stops 2 and 3.

Nature Conservancy: The Nature Conservancy has, over time, purchased more than 30,000 acres of lands in the Beezley Hills as well as north into upper Moses Coulee. These purchases were driven by the desire to preserve and restore shrub steppe biotic communities here. Much of the land that we drive through between Stop 2 and Stop 4 is now owned (and preserved) by the Nature Conservancy.

Monument Hill to Upper Lynch Coulee

Route: Continue approximately 3 miles east and north on P NW to its junction with the Baird Springs Road. At this junction, turn west (left) and drive less than 0.25 miles to the prominent roadcut along the road. Park along the south side of the road so we can better see the outcrop on the north side.

Stop 2—Monument Hill

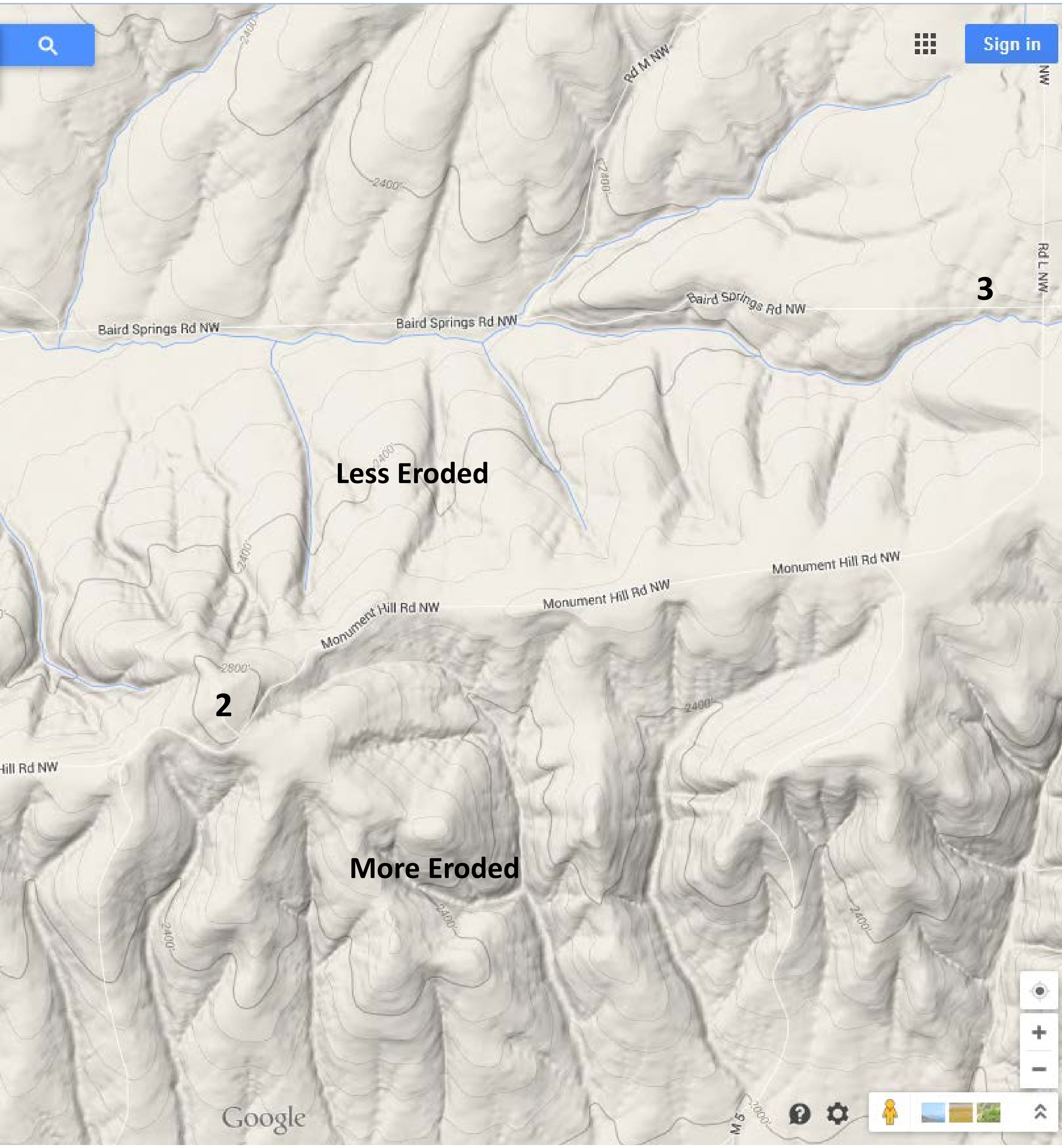


Figure 13. Erosional differences in the Beezley Hills. Numbers indicate locations of Stops 1 and 2. Source: Google Maps.

Figure 14. Monument Hill and patterned ground surrounding. Source: Google Earth.

Stop 3—Upper Lynch Coulee

Location: We are located just west of the intersection of P NW and Baird Springs roads at a prominent roadcut through fine-textured sediment.

Loess: Sediments exposed in this ~11 foot tall roadcut (Figure 15) are fine sand-, silt-, and clay-sized and lack obvious bedding. The size and absence of prominent beds in the sediments, combined with the overall thickness, suggest an airfall origin for this entire deposit. This loess may have originated as: 1) glacial outwash from the Okanogan Lobe (Hobbs, 1947; Markham, 1971); 2) alluvium in the Ringold Formation that outcrops in the Quincy and Pasco basins (Culver, 1937; Newcomb, 1958); 3) glacial outwash in the Columbia River Valley (Waitt, 1983); and 4) Touchet Beds deposited in Missoula Flood slackwater in the Quincy and Pasco Basins as well as the Walla Walla and Yakima River valleys (Ludwig, 1987; Busacca and McDonald, 1994). The decreasing size and thickness of sediments from southwest to the northeast (Figures 16 & 17) support a slackwater sediments origin for the loess. Elsewhere on the Columbia Plateau, three separate loess units are present suggesting three loess deposition episodes which bracket two episodes of late Pleistocene flooding in the past ~80,000 years (Figure 18). My very preliminary examination of this outcrop (~2 hours including sampling) suggests two loess units are present (Figure 15). This differentiation is based on soil development (see below).

A brief introduction to soil development: Soils typically form from the surface downward in a parent material such as loess. Complicating matters, though, is the fact that loess is not all deposited at one time; instead, it slowly accumulates over time building up the soil as the soil develops downward. Different soil horizons form from different processes within a particular parent material over time. Clays and carbonates move from upper to lower horizons with time. Clay-rich accumulations at depth indicate mature soils. Semi-arid climates such as this are not sufficiently wet to completely flush carbonates out of a soil. Instead, they accumulate below the clay-rich horizons in a particular soil, and appear as white streaks to rock-like white layers. The rock-like material is commonly referred to as caliche or hardpan. This soil is primarily classified as the Renslow Series which has been classified as a coarse-silty, mixed, mesic, Aridic, Calcic, Argixeroll (Gentry, 1984). This "soil speak" essentially means that the Renslow has a coarse-silty texture, mixed mineralogy, formed in a Quincy-like temperature and precipitation regime, has accumulations of calcium carbonate and clay, and formed beneath native grasslands.

Environmental history: The preliminary examination of this outcrop suggests that periods of loess accumulation, landscape stability (hence soil development), and soil erosion. Following deposition of L2 between distinct flood periods, the lower soil formed (Figure 15). This soil likely included an A horizon as well as the Bt (clay-rich) and Bk (carbonate-rich) horizons. The ample clay of the Bt horizon suggests that this soil formed over a long period of time. The laminated nature of the Bk horizon (Figure 19 & Table 1) indicates that it is a Stage V carbonate, also suggesting it is of great antiquity. This is supported by Bretz (1956, p. 969) who states *"a heavy caliche is believed to distinguish the prescabland surface over much of the region."* A subsequent period of erosion occurred removing the A horizon of this lower soil. L1 was then deposited over L2. In the stable period that followed, soil subsequently formed in L1 including A (organic-influenced mineral horizon), Bw (slightly weathered mineral horizon), Bt, and Btk (clay- & carbonate-rich) horizons. The presence of clay and carbonate at depth indicate that this too is an old soil but not to the degree of the lower soil. My students and I are currently doing more in-depth analyses on the seven units identified in the field to better understand loess deposition and soil formation in this environment.

Stop 3—Upper Lynch Coulee

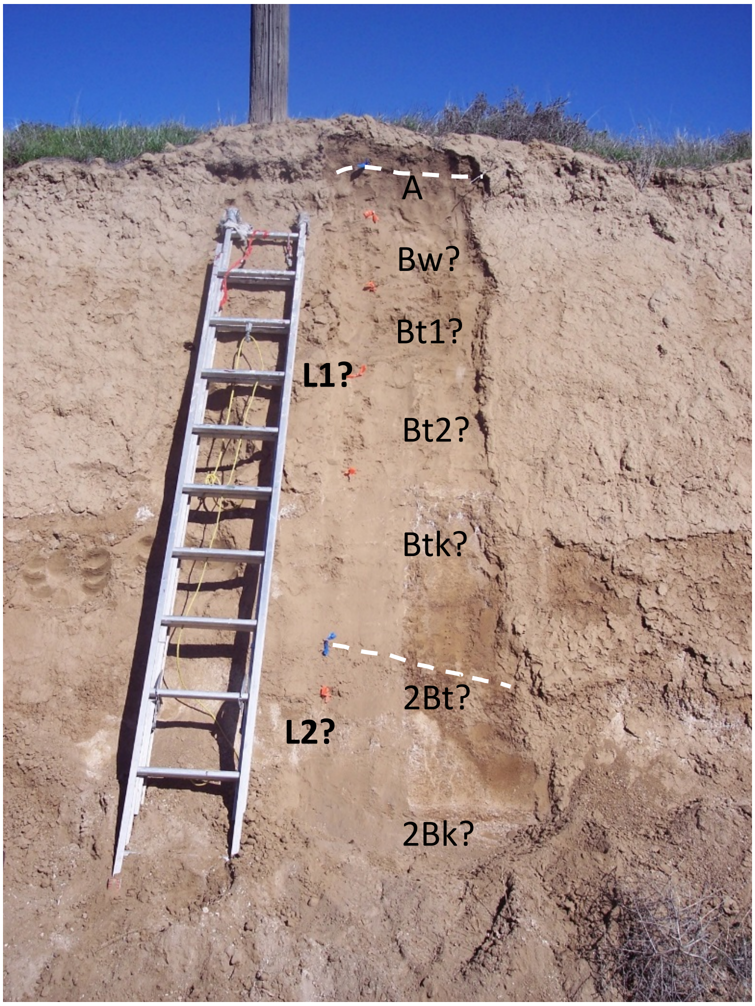


Figure 15. Loess exposure in upper Lynch Coulee, Beezley Hills. Dashed lines indicate possible discontinuities representing different loess units. L1 and L2 are loess units. Unit above upper dashed line is L1 loess moved by dryland farming activities. A, Bw?, Bt1?, Bt2?, Btk?, 2Bt?, and 2Bk? represent soil horizons formed in the loess. Source: Author photo.

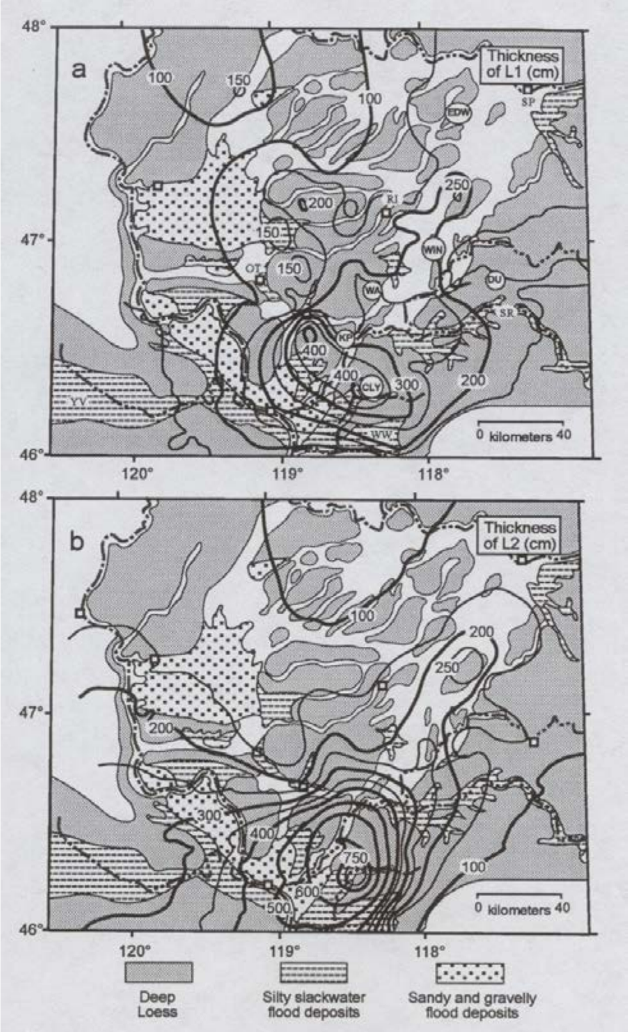


Figure 16. Contour maps of thickness of (a) L1 loess and (b) L2 loess across Columbia Plateau. Contour intervals are 100 micrometers for the major contours and 50 micrometers for the thin contours. Source: Busacca and McDonald (1994).

Stop 3—Upper Lynch Coulee

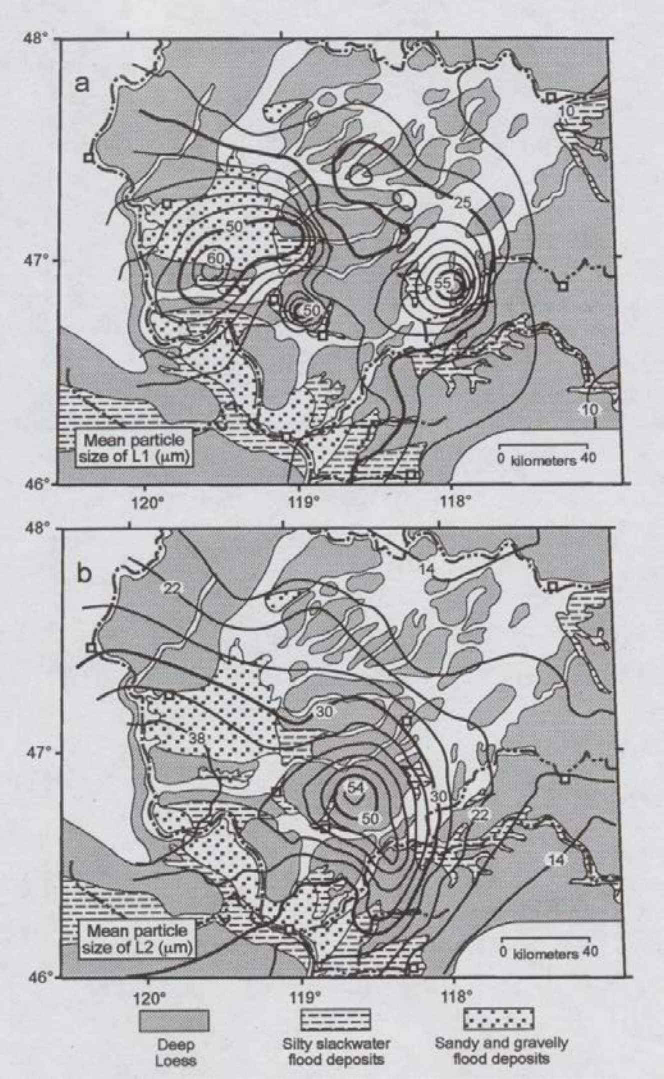


Figure 17. Contour maps of mean particle size in micrometer of (c) L1 loess and (d) L2 loess across the Columbia Plateau. Bold contours are 20 micrometer intervals and thin contours are 4 micrometer intervals. Source: Busacca and McDonald (1994).

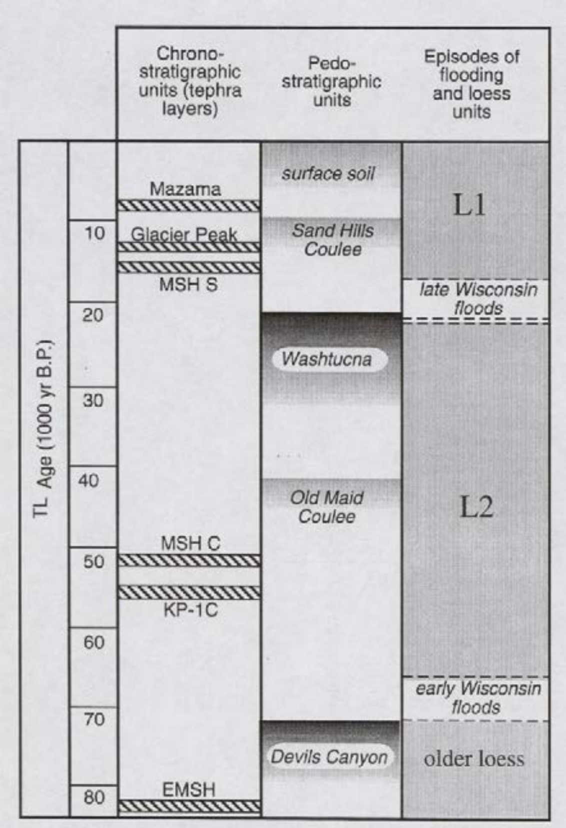
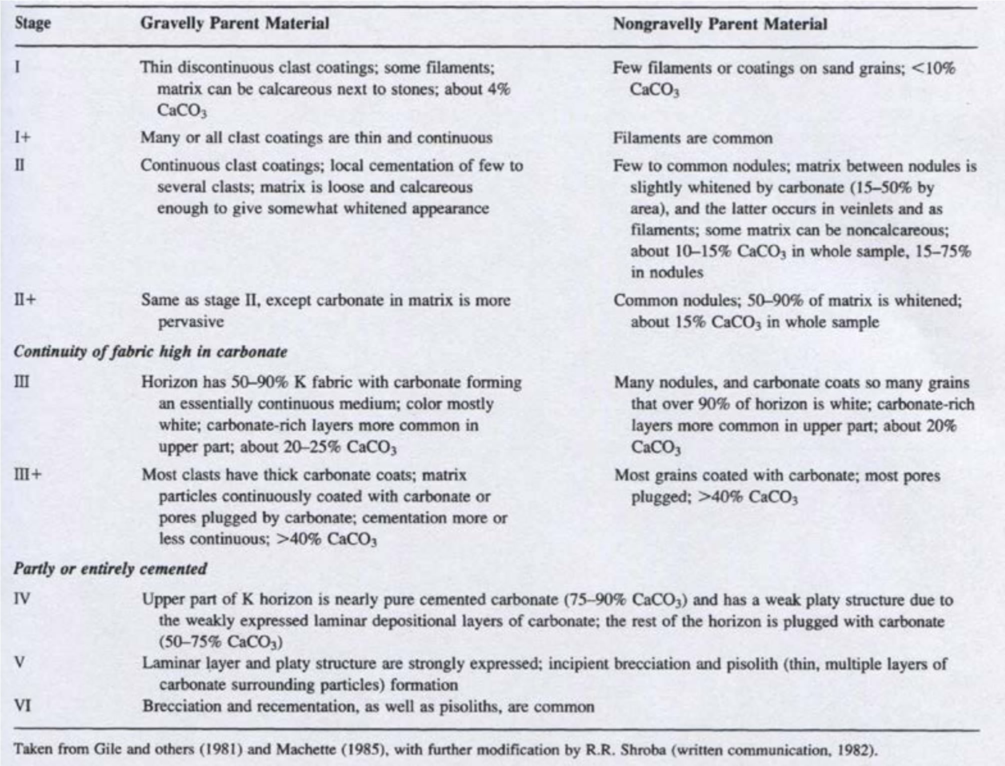


Figure 18. Composite schematic stratigraphic diagram of late Quaternary volcanic ash layers, soils, loess, and cataclysmic flooding events on the Columbia Plateau. Source: Busacca and others (2002).

Stop 2—Upper Lynch Coulee

Figure 19. Bk horizon with Stage V carbonate at base of upper Lynch Coulee, Beezley Hills roadcut. Source: Author photo.



Stage	Gravelly Parent Material	Nongravelly Parent Material
I	Thin discontinuous clast coatings; some filaments; matrix can be calcareous next to stones; about 4% $CaCO_3$	Few filaments or coatings on sand grains; <10% $CaCO_3$
I+	Many or all clast coatings are thin and continuous	Filaments are common
II	Continuous clast coatings; local cementation of few to several clasts; matrix is loose and calcareous enough to give somewhat whitened appearance	Few to common nodules; matrix between nodules is slightly whitened by carbonate (15–50% by area), and the latter occurs in veinlets and as filaments; some matrix can be noncalcareous; about 10–15% $CaCO_3$ in whole sample, 15–75% in nodules
II+	Same as stage II, except carbonate in matrix is more pervasive	Common nodules; 50–90% of matrix is whitened; about 15% $CaCO_3$ in whole sample
Continuity of fabric high in carbonate		
III	Horizon has 50–90% K fabric with carbonate forming an essentially continuous medium; color mostly white; carbonate-rich layers more common in upper part; about 20–25% $CaCO_3$	Many nodules, and carbonate coats so many grains that over 90% of horizon is white; carbonate-rich layers more common in upper part; about 20% $CaCO_3$
III+	Most clasts have thick carbonate coats; matrix particles continuously coated with carbonate or pores plugged by carbonate; cementation more or less continuous; >40% $CaCO_3$	Most grains coated with carbonate; most pores plugged; >40% $CaCO_3$
Partly or entirely cemented		
IV	Upper part of K horizon is nearly pure cemented carbonate (75–90% $CaCO_3$) and has a weak platy structure due to the weakly expressed laminar depositional layers of carbonate; the rest of the horizon is plugged with carbonate (50–75% $CaCO_3$)	
V	Laminar layer and platy structure are strongly expressed; incipient brecciation and pisolith (thin, multiple layers of carbonate surrounding particles) formation	
VI	Brecciation and recementation, as well as pisoliths, are common	

Taken from Gile and others (1981) and Machette (1985), with further modification by R.R. Shroba (written communication, 1982).

Table 1. Stages of soil carbonate morphology. Source: Birkeland (1999, p. 357).

En route to Stop 4

Route: We follow the Baird Springs Road approximately 7 miles down Lynch Coulee to Overen Road. Baird Springs lies on the northeast side of this intersection. We will turn north (right) onto Overren Road, drive a short distance, and park along the side of the road.

Coulees. In this region, "coulee" often refers to a steep-sided, flat floored valley eroded into basalts by huge ice age floods. Lynch Coulee originates atop the Beezley Hills just east of Stop 3 at an elevation of ~2640 feet. No landform or sediment evidence has been found to indicate that Missoula Floods or any other ice age floods formed the coulee, and the elevation appears much too high for floods to have entered the coulee from above. Instead, Lynch Coulee is likely the product of long-term stream erosion (Figure 20). The well-developed soils that indicate long term landscape stability in the area support a non-flood origin for the coulee. Such long term stability is only possible without having been inundated by glacial ice or massive floods.

Farming and Homesteads: At least one abandoned farmstead is present along the Baird Springs road as we descend Lynch Coulee. Vegetation patterns in the coulee also indicate that much land that was once farmed has been taken out of agricultural production. Some of this land is now owned by the Nature Conservancy. Similar land is owned by other private landowners but is no longer farmed. Much of this land went out of production in the mid-1980's as part of the Conservation Reserve Program as a way to prevent erosion on lower quality, highly erodible lands. An unforeseen benefit of the CRP was that it created much new wildlife habitat here and elsewhere in central Washington.

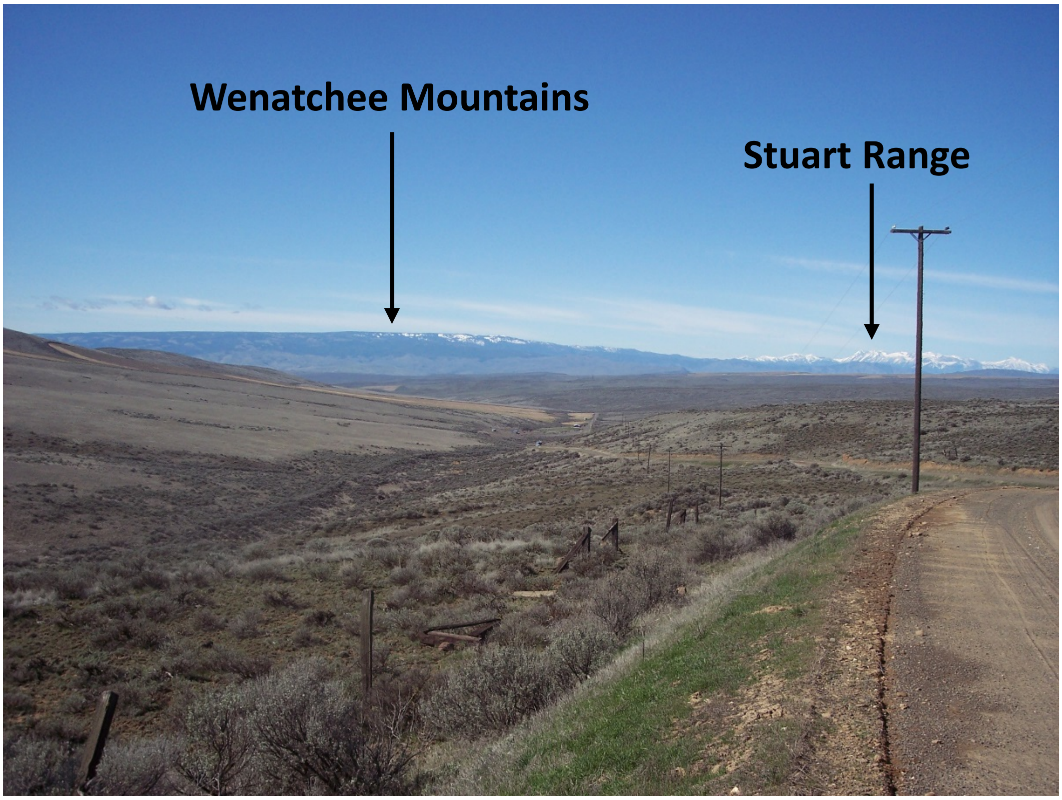


Figure 20. View down (west) upper Lynch Coulee from near Stop 3. Note the Wenatchee Mountains and the Stuart Range in the background. Source: Author photo.

Stop 4—Baird Springs (Middle Lynch Coulee)

Location: We are located on Overen Road just north of its junction with the Baird Springs Road. This is property owned by the Nature Conservancy.

Arroyos and Their Formation: Arroyos (or gullies) are steep-walled channels incised into cohesive, fine-textured sediments in semi-arid to arid settings. They often form as a steep headcut that erodes headwardly (upstream). Arroyos may form in overall wet or dry climatic periods. They are often initiated by intense precipitation or rapid snowmelt weather events. Land conditions may determine the susceptibility of erosion creating arroyos. For example, overgrazing of upland or riparian vegetation by cattle or native wildlife may reduce root strength thereby allowing arroyos to initiate. Beavers may also destroy riparian vegetation to build dams. While vegetation destruction enhances arroyo formation, beaver dams help prevent it. As you can see from the above, one distinct cause of arroyo incision does not exist. Instead, it is likely that multiple triggers exist depending on the situation. In the field of geomorphology (i.e., study of landforms and the processes that create them), we refer to multiple causes for the same phenomenon as "equifinality.

Central Washington Arroyos: Prominent arroyos are found throughout Central Washington including Park Creek and Ryegrass east of Ellensburg along I-90, Johnson Creek and Hanson Creek on the Yakima Training Center, Weber Coulee and Bauer Coulee along I-90 west of Ritzville, and Foster Creek on the northern Waterville Plateau. At Foster Creek, former CWU Resource Management student Paul Blanton found that arroyo incision was likely triggered by flood events in 1922 and 1948 on land that was being intensively farmed. Incision increased most between 1939 and 1955. Changing land use as a result of the Conservation Reserve Program reversed this trend beginning in the 1980's (Blanton, 2004).

Baird Springs Arroyo and its Formation: The Baird Springs arroyo system extends discontinuously up the unnamed drainage to our north, and up and down the mainstem of Lynch Coulee (Figure 21). It ranges from ~10 to nearly 30 feet deep, and ~20 to 50 feet wide. In places, it is floored by basalt bedrock while in others its floor is unconsolidated sediment. Given the presence of springs here, the area was likely used by Native Americans, and later by Euroamericans. However, human use of the site likely changed dramatically with the incision of the arroyo as it would have drastically changed the hydrology of the area. I assume streams, at least ephemerally, and perhaps seasonally, flowed down the mainstem Lynch Coulee and the side channel we are on. The dark, organic-rich surface soil here suggests that the side canyon stream was at the surface forming a broad wet meadow. This wet meadow would have included various water-loving plants, perhaps including riparian (i.e., water-loving) trees and shrubs. With incision, the stream flowed in the bottom of the arroyo, lowering the local water table, and cutting off surface and subsurface flow to the wet meadow. Incision also confined the stream to this relatively narrow channel so subsequent flood events likely resulted in more incision rather than dissipating energy across a broad flood plain. Further incision would lead to more sediment being flushed downstream.

Timing of Baird Springs Arroyo Formation: We don't know when this arroyo formed. A core taken from a large cottonwood on the floor of the arroyo only had 20 annual rings suggesting that it formed before 1995. I suspect that the feature is well older than 20 years based on the amount of debris that has accumulated at the base of the arroyo walls and the vegetation that is growing on the channel floor. More tree cores mighthelp as could conversations with local farm families and perhaps county road maintenance crews. Airphotos too could shed light as they exist for this area back at least to 1949. If we can pin down a date of formation within historical times, we may be able to sort out its cause(s).

Stop 4—Baird Springs

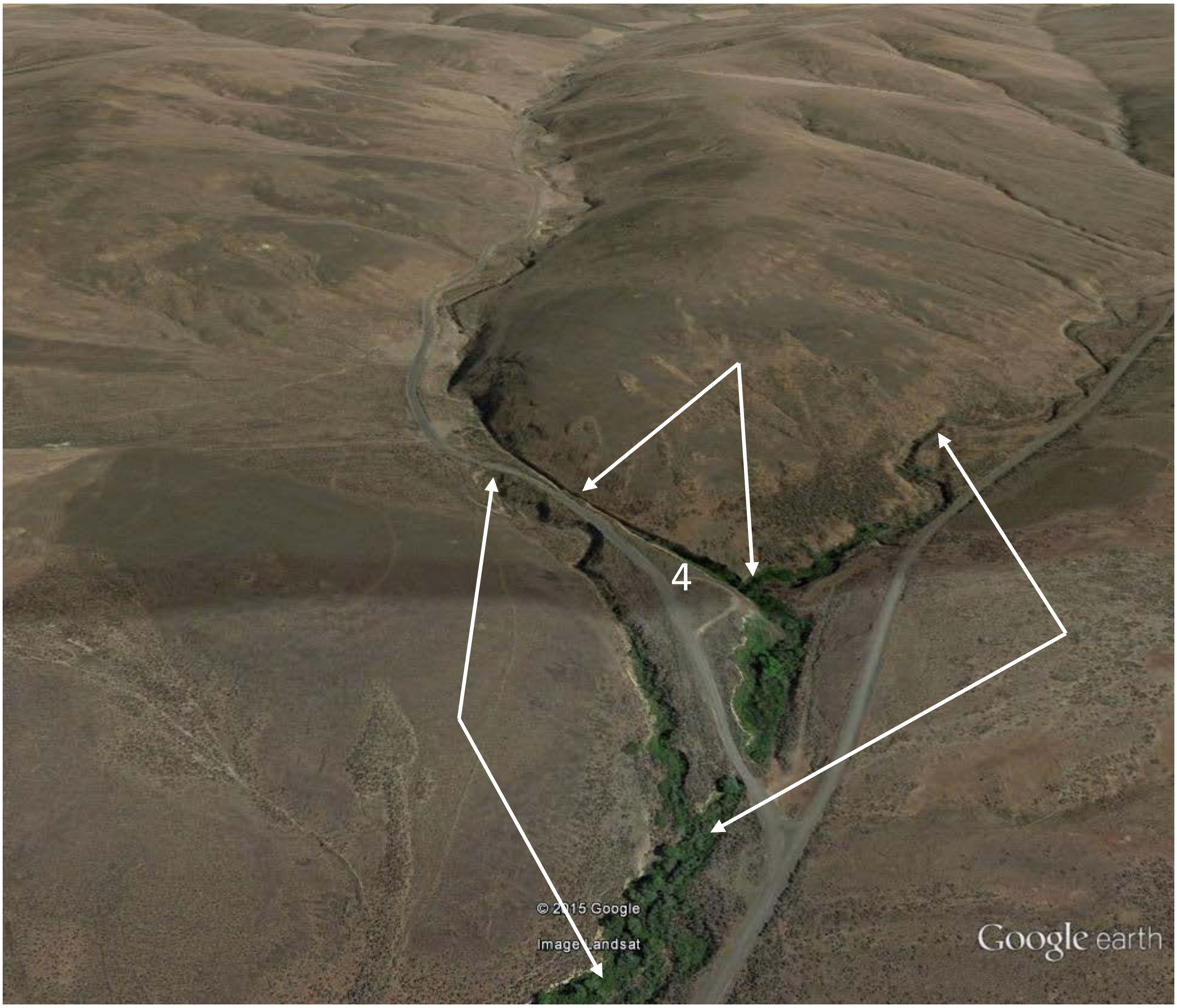


Figure 21. Oblique view of Baird Springs area. Arrows point to incised portions of floodplains in Lynch Coulee and unnamed side canyon. Number indicates field stop site. View toward northeast. Source: Google Earth.

Environmental History: While arroyo incision may cause sedimentation problems downstream, arroyos, like roadcuts, may be rich repositories of environmental history. Baird Springs Arroyo appears to offer such a history in little studied part of central Washington. Brief observations (~2 hours including tephra sampling) lead to the following very preliminary interpretations: 1) deposition of coarse-textured alluvium by high energy floodwaters in the late Pleistocene/early Holocene (Figure 22); 2) deposition of finer-textured alluvium in a lower energy, late Pleistocene/early Holocene environment; 3) deposition of Mazama ash ~7600 calendar years before present; 4) deposition of more finer-textured alluvium in the mid- to late Holocene; 5) late Holocene soil formation in valley floor, wet meadow; and 5) incision of the arroyo into the valley floor in historic? times.

Stop 4—Baird Springs

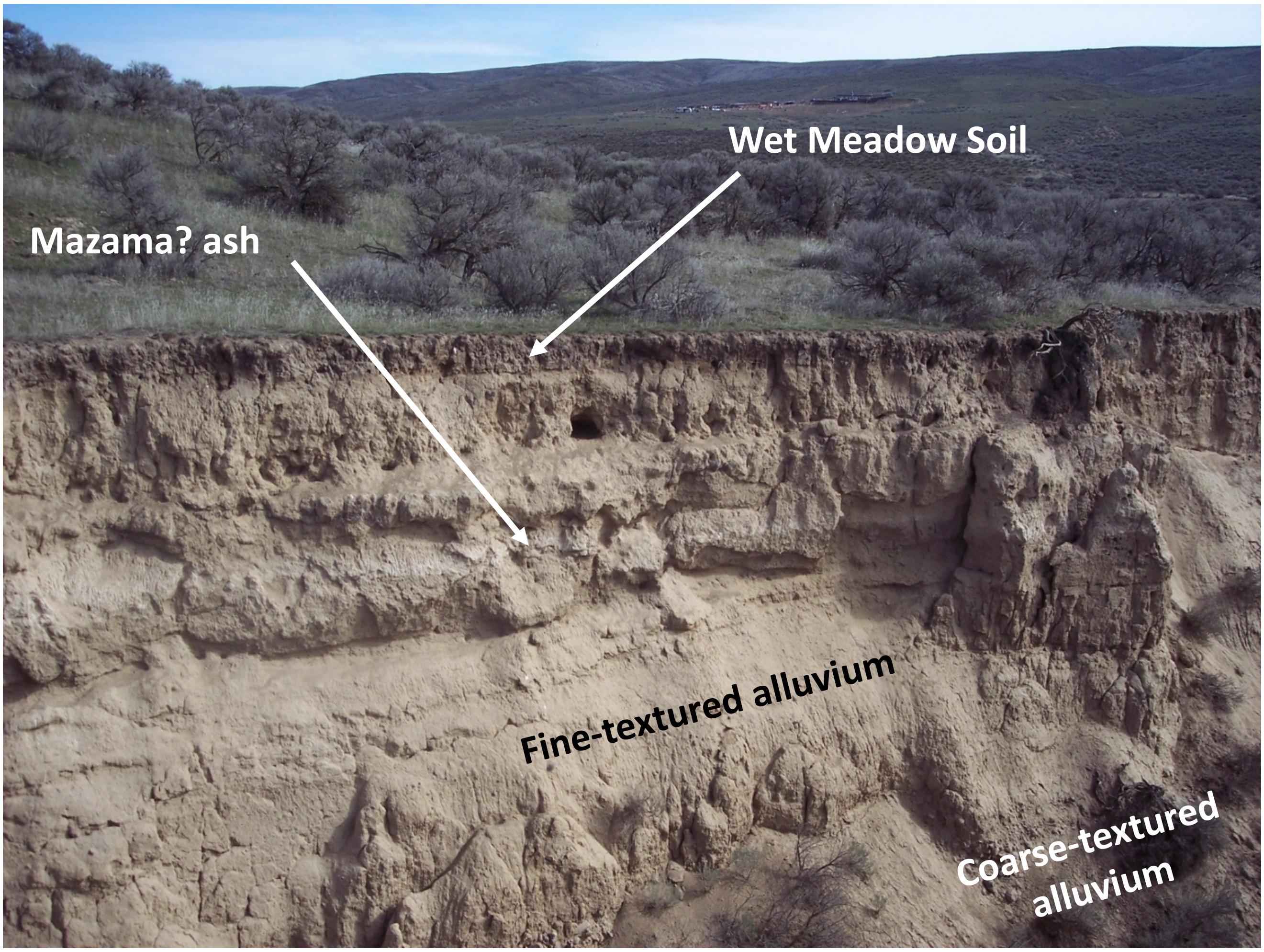


Figure 22. Cross-section view of a part of the Baird Springs arroyo, unnamed drainage ~100 feet upstream of junction with Lynch Coulee. Note different sediment and soil units. Source: Author photo.

Baird Springs to Crater Coulee

Route: Return on Overeren Road to to Baird Springs Road. At the intersection, turn southwest (right) and head downvalley. Drive approximately 6 miles to the intersection of Baird Springs Road with W NW. Turn north (right) onto W NW and follow it midway up the hill to a viewpoint of Crater Coulee.

Biosolids: Approximately 1 mile downvalley of Baird Springs proper is Baird Springs Environmental SMF's biosolids lagoon and land application site. Baird Springs Environmental has a permit from the Washington State Department of Ecology to land apply biosolids to farmland in the area.

Terracettes: Terracettes are small, terrace-like features that occur repeatedly on steep terrain. They occur throughout the world in semi-arid and arid settings, and are common throughout steep terrain on the Columbia Plateau. Some have attributed their origins to mass wasting (i.e., sliding and creeping) while others note that they are a result of hooved animals traversing slopes. Moist soil may enhance their formation as they appear best developed in middle and lower Lynch Coulee on north-facing slopes (Figure 23).

Figure 23. Terracettes in lower Lynch Coulee. Source: Author photo.

Great Northern Railroad: As the Great Northern Railroad was built across the Western Columbia Plain, a route had to be found into the Columbia River Valley. West of Quincy, this route turned out to be partly in the ice age flood channel now known as Crater Coulee. From Crater Coulee, the right-of-way looped upvalley along the margins of Lynch Coulee, crossed the coulee, then headed downvalley into the Columbia River Valley. We cross through a tunnel in the railroad fill across Lynch Coulee.

Stop 5—Crater Coulee (Lower Lynch Coulee)

Location: We are located on road W NW across lower Lynch Coulee from the mouth of Crater Coulee.

Crater Coulee and its Formation: J Harlen Bretz (1928a) first recognized Crater Coulee ("Crater Cateract") as the northernmost and the smallest of three catastrophic flood-created cataracts in the western Quincy Basin. The other two were the cataracts at Potholes Coulee and Frenchman Springs Coulee (Figure 8). He discussed these cateracts (including Crater Cataract) in subsequent papers (1928b, 1928c, 1930, 1956, 1959, and 1969). The following summarizes Bretz' thoughts on Crater Coulee's formation. Crater Coulee formed as floodwaters overtopped a low divide created by the Lynch Coulee anticline (Figures 10 & 24), exploiting a pre-existing, non-scabland "gulch" eroded in the western limb of the anticline to the Lynch Coulee floor below.

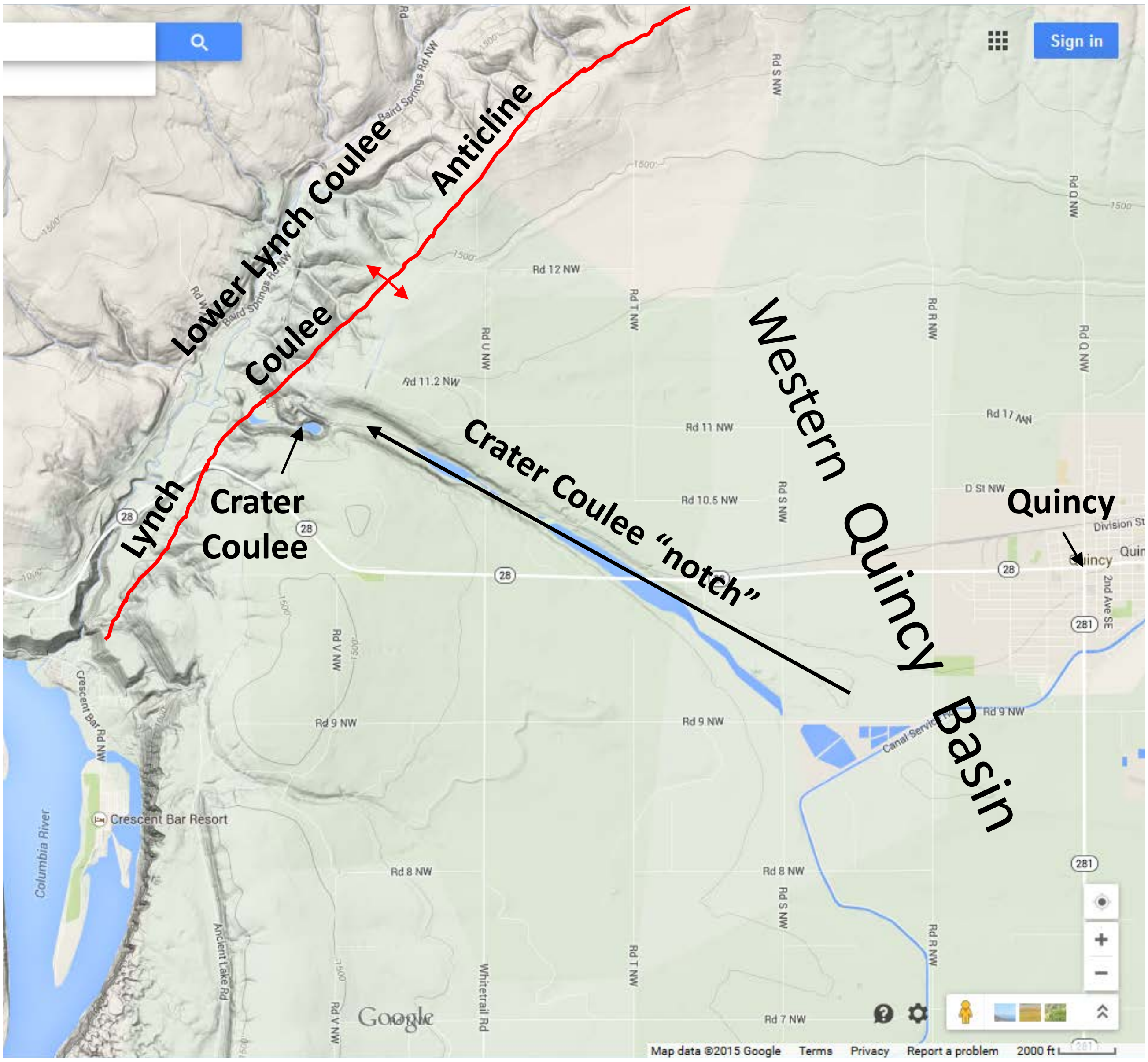


Figure 24. Crater Coulee and Crater Coulee "notch", western Quincy Basin. Large arrow indicates flood flow direction. Source: Google Maps.

Stop 5—Crater Coulee

Crater Coulee and its Formation (continued): Headward erosion of the resistant, folded basalts of the anticline's western limb must have rapidly resulted in a ~200 foot tall waterfall and a smaller, ~70 foot tall waterfall (Figure 25). With time, the Crater Cataract receded headwardly approximately 0.8 miles. Most of Crater Coulee's "notch" (or channel eroded into the eastern limb of the anticline) is intact because the waterfall receded so little.

Crater Coulee and Bretz' Catastrophic Flood Hypothesis: Bretz (1928b, 1928c, 1930, 1956, 1959, and 1969) discussed the importance of Crater Coulee, as well as Potholes Coulee and Frenchman Springs Coulee, in the catastrophic flood story. The fact that each of the outlets cuts across a topographic divide suggests that huge amounts of water were present in Quincy Basin. Further, common elevations for the upper levels of entrenchment (~1300 feet) suggest all three outlets operated contemporaneously to drain floodwaters from the Quincy Basin. Such contemporaneous operation was a key piece to arguing that floods, not long-term diversion of a "normal" Columbia River, resulted in the erosion of each of the four outlets at different times. Bretz (1956) attributed Crater Coulee's slightly (~70 feet) higher elevation to lower flood discharge and shorter use as a floodway on the northern margins of the basin compared to Potholes and Frenchman Springs coulees to the south. He also notes that the bedrock and sediment-filled plunge pool basin of Crater Coulee suggests discharge through Crater Coulee decreased rapidly because Frenchman Springs and Potholes coulees deepened faster. My observations indicate that the rim of Waterfall B (Figure 25) is ~70 feet higher than that of Waterfall A (~1320 feet vs. 1250 feet). This may suggest that larger flow through the area created both waterfalls but as water levels dropped, flow concentrated at Waterfall A.

Lower Lynch Coulee: Bretz (1930) refers to this as Willow Creek Draw. Upstream of Crater Coulee, the valley floor averages about 400 feet in width (Figure 26). Conversely, the valley floor downstream of the coulee mouth is closer to 800 feet wide, and has a lower gradient. This increased width and lower gradient is the result of floodwaters descending Crater Coulee into Lynch Coulee. The slopes of Lower Lynch Coulee are also truncated as a result of flood erosion (Figure 26). Bretz (1930) first recognized the low gradient, gravel fill of the floor of Lower Lynch Coulee that stretches from the mouth of Crater Coulee to Trinidad. Waitt (1977) identified two distinct, but similar-aged flood deposits in the Lower Lynch Coulee fill. The lower sediments indicate flow upvalley (into Lynch Coulee) and the upper sediments show downvalley flow (likely from Crater Coulee). This fill will be one of the topics of Stop 6.

Columbia Valley Floods in Crater Coulee: "Slightly bruised" columnar [basalt] fragments in mostly unsorted gravels containing caliche, other basalts, siltstones, and loess at the head of Crater Coulee suggest eastward flow of cataclysmic floodwaters from the mainstem Columbia River through Crater Coulee (Bretz, 1969). Based on this and other evidence in the area, it appears huge Columbia Valley floods preceded the humongous outpourings from the Grand Coulee and Crab Creek. In a subsequent field trip we will explore other evidence for such flooding in the Quincy Basin.

Stop 5—Crater Coulee

Figure 25. Crater Coulee cataract. Arrows indicate floodwater movement directions. Letters indicate plunge pools. View toward east. Source: Google Earth.

Stop 5—Crater Coulee

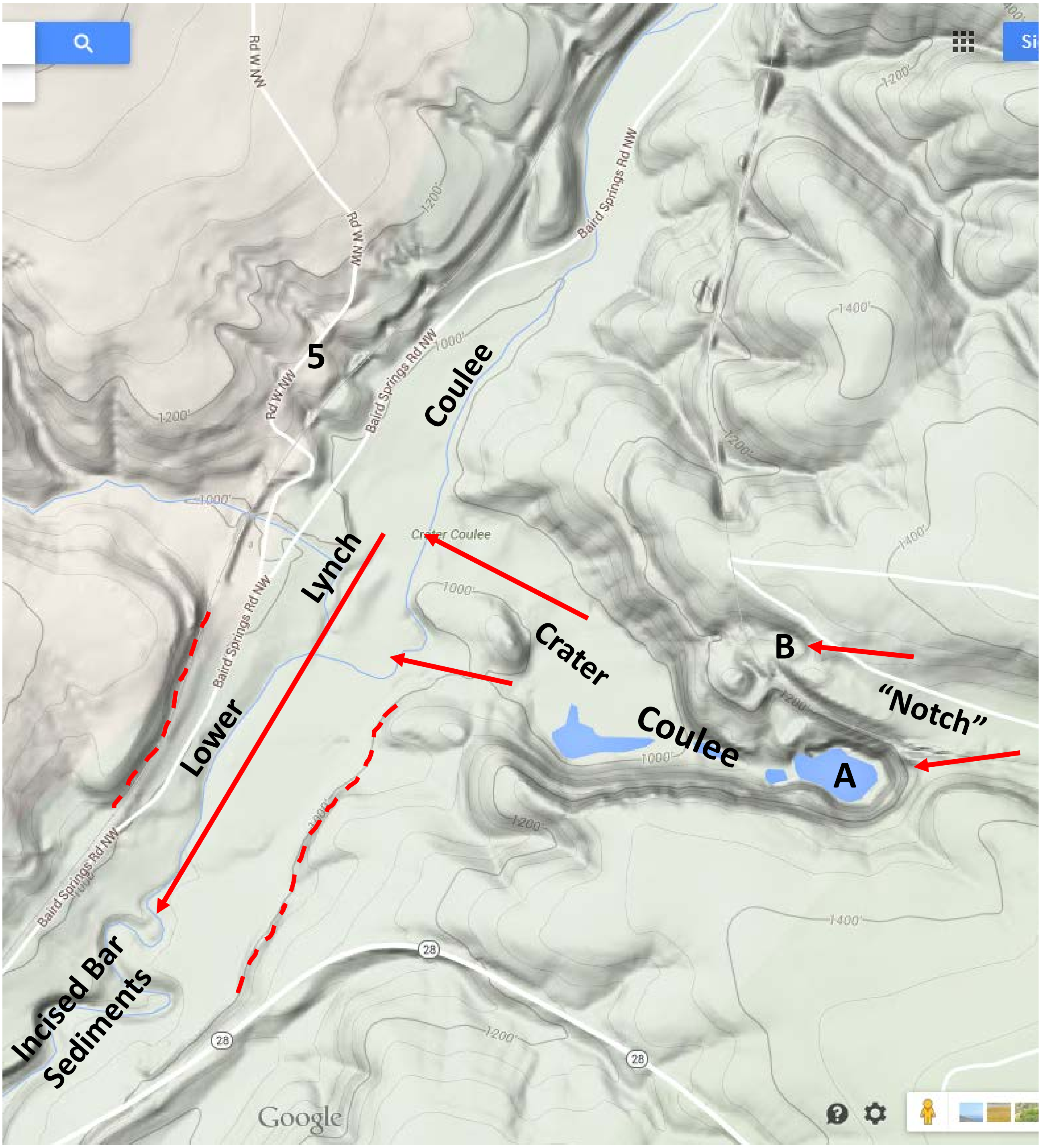


Figure 26. Crater Coulee and Lynch Coulee. Note the double, albeit unequal sized, plunge pools in the Crater Coulee cataract. Note the width difference between Lynch Coulee above and below Crater Coulee. Also, note the abrupt east and west walls of Lower Lynch Coulee below Crater Coulee (dashed) that resulting from floodwater erosion. Letters indicate plunge pools. Source: Google Maps.

Crater Coulee to West Bar Overlook

Route: Return to Baird Springs Road and turn southwest (right). Follow this to its junction with WA 28. After stopping, driving across WA 28 onto Crescent Bar Road. Follow this around to the west to a large, bare gravel area overlooking West Bar. This is Stop 6.

Stop 6—West Bar Overlook

Location: We are located atop a gravel pit in a paleo-flood bar near Trinidad.
Potholes Coulee Downstream: Potholes Coulee, the largest of the Western Quincy Basin outlets, enters the Columbia River Valley ~6 miles downstream. This double cataract is 1.4 miles wide and 380 feet, both dimensions comparable to the better known and more visited Dry Falls at the head of the Lower Grand Coulee.
Trinidad Bar: The bar we are standing on, Trinidad Bar, is composed of foreset beds that dip upvalley yet the mixed rock types within suggest an upvalley source. Waitt and others (2009) attribute this apparent discrepancy to a catastrophic flood moving down the Columbia River Valley, rounding the large bend to the west, and eddying back to the north. This huge eddy resulted in an eddy bar composed of more than 300 feet of sand and gravel (Figure 27). I estimate that this bar is 2 miles long, and stretches up Lynch Coulee to near Crater Coulee's mouth. Near where we stand, Waitt, in 1994, identified ~19 separate floods in rhythmic sediment units. Mount St. Helens S tephra dated at ~13,500 ^{14}C yr BP (~15,500 calendar years) is found midway down through the stack of rhythmites giving us a sense of the age of the flooding (Waitt and others, 2009).
West Bar: West Bar lies across the river and ~100-200 feet below us. It is a giant crescent (or point) bar formed on the inside of the channel where velocities were lower. Giant current ripples (or dunes) cover the surface of the bar, and are so large they are visible from the window of a commercial aircraft. Ripples wavelengths average ~360 feet while ripple heights average ~24 feet (Bjornstad and others, 2007). Bretz used the giant current ripples as a key piece of his evidence of huge floods rather than uniform flow shaping the landscape. The lower elevation of West Bar compared to Trinidad Bar indicated to Bretz (1930) that West Bar is younger. The bar itself may have formed from Missoula Floods. The size, shape, and orientation and location of the giant current ripples indicate that they formed from one of the last ice age floods to descend the Columbia River Valley. However, the source was probably not from Glacial Lake Missoula; rather, it was likely from the breakup of the Okanogan Lobe and the release of Glacial Lake Columbia (Bretz, 1969; Waitt, 1994). It may have also originated from Glacial Lake Kootenay (Waitt, 2009).

Stop 6—West Bar Overlook

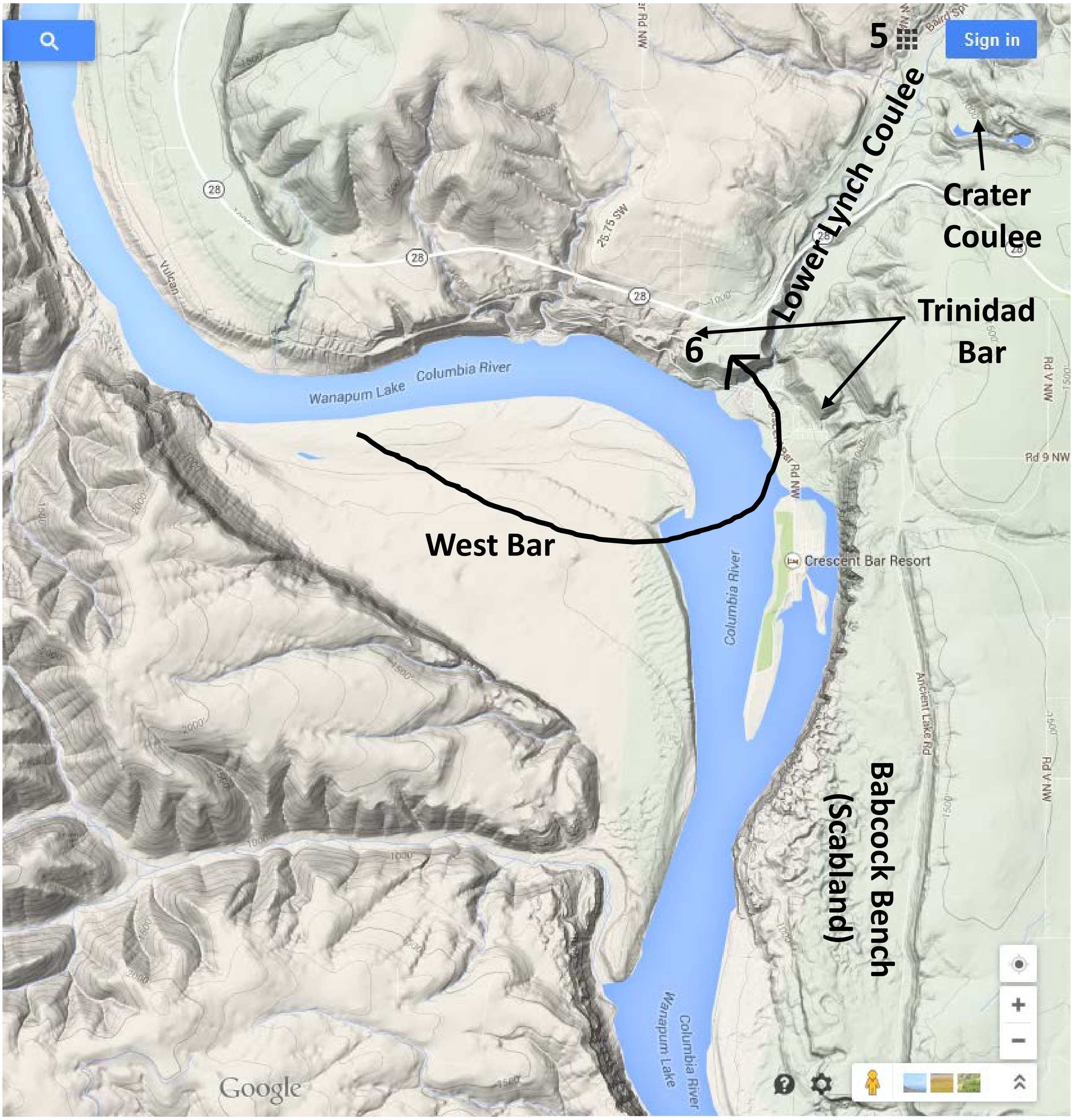


Figure 27. Trinidad and West Bar areas, mid-Columbia River. Arrow indicates large eddy in catastrophic floods that led to the deposition of Trinidad Bar. Source: Google Maps.

Stop 6—West Bar Overlook

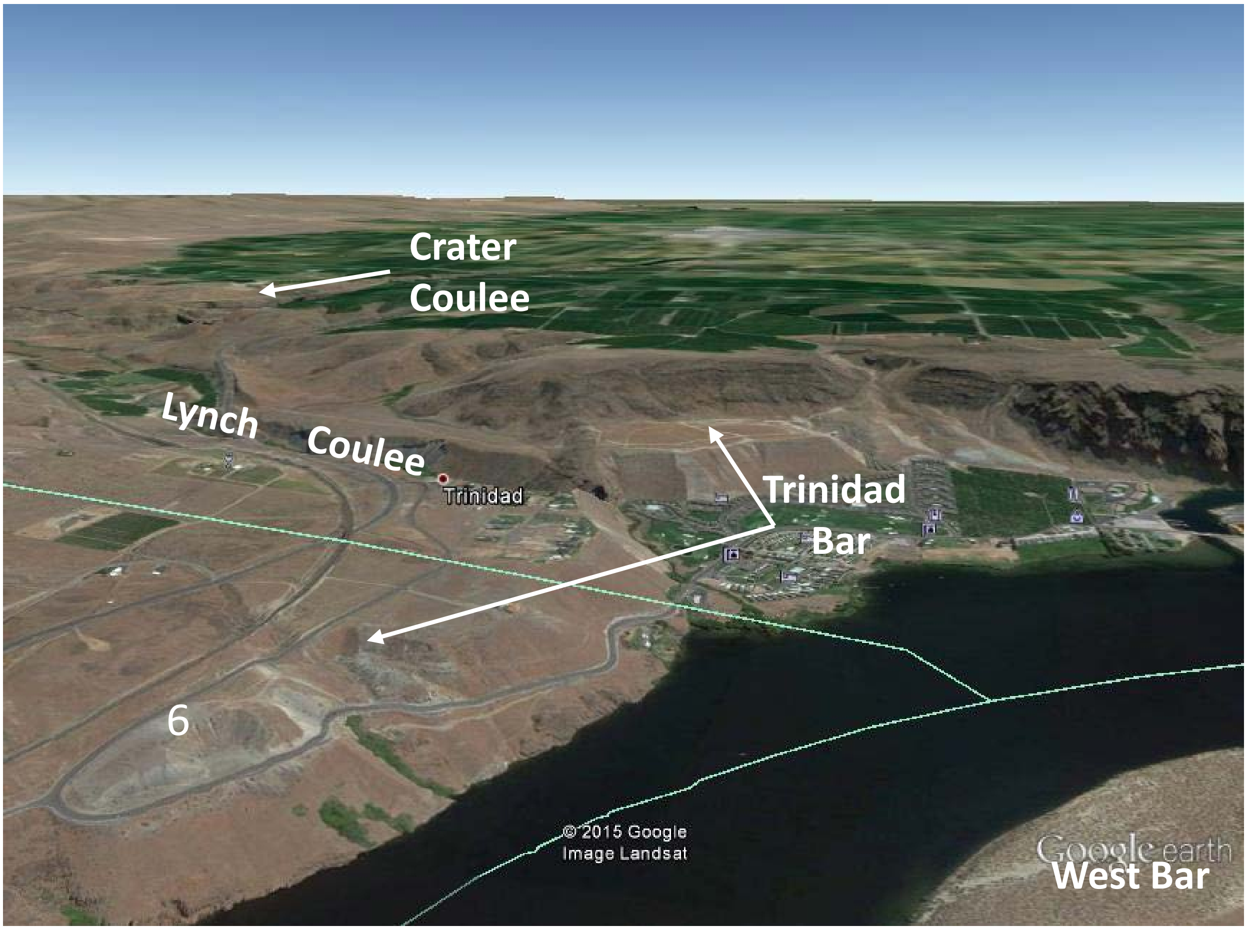


Figure 28. Trinidad Bar at the mouth of Lynch Coulee, mid-Columbia River. View east. Source: Google Earth.

West Bar Overlook to Quincy Valley Rest Area

Route: Return to the intersection of Crescent Bar Road and WA 28. Turn east (right) onto WA 28 and follow it approximately 3 miles to the Quincy Valley Rest Area. This is the last stop of the field trip, and its sole purpose is to serve as a much-needed restroom stop. Thanks for field tripping with us today!

Selected References

- Birkeland, P.W. 1999. *Soils and Geomorphology* (3rd edition). Oxford University Press, New York.
- Bjornstad, B.N. 2006. *On the Trail of the Ice Age Floods: A Geological Field Guide to the Mid-Columbia Basin*. Keokee Company Publishing, Inc. Sandpoint, ID.
- Bjornstad, B.N., R.S. Babcock and G.V. Last. 2007. Flood basalts and ice age floods: Repeated late Cenozoic cataclysms of southeastern Washington. Pp. 209-255 in Stelling, P and Tucker, D.S., eds., *Floods, Faults and Fire: Geological Field Trips in Washington State and Southwest British Columbia*. Geological Society of America Field Guide 9.
- Blanton, P. 2004. Historical Arroyo Development in the West Foster Creek Watershed, Washington: Spatial Extent, Timing, Causes, and Management Implications. M.S. Thesis, Central Washington University.
- Bretz, J H. 1928a. The Channeled Scabland of Eastern Washington. *Geographical Review* 18 (3): 446-477.
- Bretz, J H. 1928b. Alternative hypotheses for Channeled Scabland. I. *Journal of Geology* 36 (3): 193-223.
- Bretz, J H. 1928c. Alternative hypotheses for Channeled Scabland. II. *Journal of Geology* 36 (4): 312-341.
- Bretz, J H. 1930. Valley deposits immediately west of the Channeled Scabland. *Journal of Geology* 38)5): 385-422.
- Bretz, J H. 1959. Washington's Channeled Scabland. *Washington Division of Mines and Geology Bulletin 45*.
- Bretz, J H. 1969. The Lake Missoula Floods and the Channeled Scabland. *Journal of Geology* 77: 505-543.
- Bretz, J H., H.T.U. Smith and G.E. Neff. 1956. Channeled Scabland of Washington: New data and interpretations. *Bulletin of the Geological Society of America* 67: 957-1049.
- Busacca, A.J. and E.V. McDonald. 1994. Regional sedimentation of Late Quaternary loess on the Columbia Plateau: Sediment source areas and loess distribution patterns. Pp. 181-190 in Lasmanis, R. and E.S. Cheney, convenors, Regional Geology of Washington State. *Washington Division of Geology and Earth Resources Bulletin* 80.
- Busacca, A.J., D.R. Gaylord and M.R. Sweeney. 2002. Paired Eolian Deposits and Megaflood Features, Columbia Plateau, Washington. Friends of the Pleistocene 10th Annual Pacific Northwest Cell Field Trip. 16-18 August.
- Campbell, N.P. 1975. A Geologic Road Log Over Chinook, White Pass, and Ellensburg to Yakima Highways. *Washington Division of Geology and Earth Resources Information Circular 54*.
- Culver, H.E. 1937. Extensions of the Ringold Formation. *Northwest Science* 11 (3): 57-60.
- Gentry, H.R. 1984. Soil Survey of Grant County, Washington. U.S. Department of Agriculture, Soil Conservation Service.
- Gulick, C.W. 1990. Geologic Map of the Moses Lake 1:100,000 Quadrangle, Washington. *Washington Division of Geology and Earth Resources Open File Report* 90-1.

Selected References (continued)

- Hobbs, W.H. 1947. *Glacial Studies of the Pleistocene of North America—I. The Glacial History of the Scabland and Okanogan Lobes, Cordilleran Continental Glacier*. J.W. Edwards. Ann Arbor, MI.
- Ludwig, S.L. 1987. Sand Within The Silt: The Source and Deposition of Loess in Eastern Washington. M.A. Thesis, Washington State University.
- Markham, D.K. 1971. Quaternary Loess Deposits of Douglas County, Central Washington. M.S. Research Paper, Washington State University.
- Meinig, D.W. 1968. *The Great Columbia Plain: A Historical Geography, 1805-1910*. University of Washington Press. Seattle.
- Newcomb, R.C. 1958. Ringold Formation of Plestocene Age in type locality, the White Bluffs, Washington. *American Journal of Science* 256 (5): 328-340.
- Reidel, S.P. and N.P. Campbell . 1989. Structure of the Yakima Fold Belt, central Washington. Pp. 275-306 in N.L. Joseph, ed., Geologic Handbook for Washington and Adjacent Areas. *Washington Division of Geology and Earth Resources Information Circular* 86.
- Tabor, R.W., R.B. Waitt, Jr., V.A. Frizzell, Jr., D.A. Swanson, G.R. Byerly and R.D. Bentley. 1982. Geologic Map of the Wenatchee 1:100,000 Quadrangle, Central Washington. *U.S. Geological Survey Map I-1311*.
- Tabor, R.W., V.A. Frizzell, Jr., J.T. Whetten, R.B. Waitt, D.A. Swanson, G.R. Byerly, D.B. Booth, M.J. Hetherington, and R.E. Zartman. 1987. Geologic Map of the Chelan 30-Minute by 60-Minute Quadrangle, Washington. *U.S. Geological Survey Map I-1661*.
- Waitt, R.B., Jr. 1977. Guidebook to Quaternary Geology of the Columbia, Wenatchee, Peshastin, and Upper Yakima Valleys, West-Central Washington. *U.S. Geological Survey Open-file Report 77-753*.
- Waitt, R.B. 1983. Tens of successive, colossal Missoula floods at north and east margins of Channeled Scabland. Friends of the Pleistocene, Rocky Mountain Cell, Guidebook for 1983 field conference, Day 2, 23 August. *U.S. Geological Survey Open-File Report 83-671*.
- Waitt, R.B., Jr. and R.M. Thorson. 1983. The Cordilleran Ice Sheet in Washington, Idaho, and Montana. Pp. 53-70 in Porter, S.C., *ed., Late-Quaternary Environments of the United States, Volume 1: The Late Pleistocene.* University of Minnesota Press.
- Waitt, R.B. with contributions from J.E. O'Conner and G. Benito. 1994. Scores of gigantic, successively smaller Lake Missoula floods through Channeled Scabland and Columbia Valley. Pp. 1K-1–1K-87 in Swanson, D.A. and Haugerud, R.A., eds., *Geologic Field Trips in the Pacific Northwest*, Geological Society of America Annual Meeting, Seattle.
- Waitt, R.B., R.P. Denlinger and J.E. O'Conner. Many monstrous Missoula Floods down Channeled Scabland and Columbia Valley. Pp. 775-844 in O'Conner, J.E., Dorsey, R.J. and Madin, I.P., eds., *Volcanoes to Vineyards: Geologic Field Trips Through the Dynamic Landscape of the Pacific Northwest*. Geological Society of America Field Guide 15. Boulder, CO.
- Western Regional Climate Center. n.d. Quincy 1 S Washington (456880). http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa6880
- Works Projects Administration. 1941. *Washington: A Guide to the Evergreen State*. Binfords and Mort. Portland, Oregon.