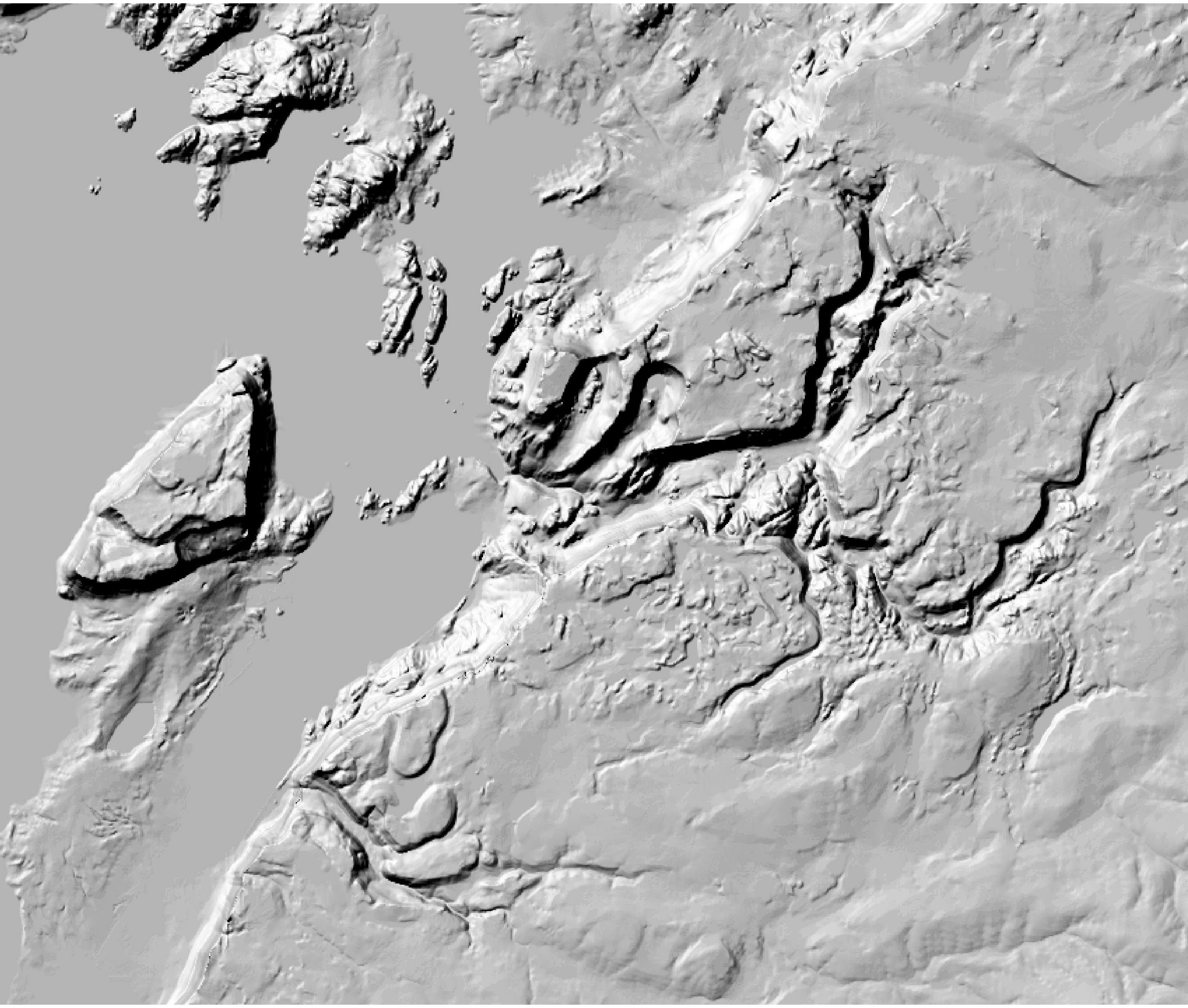
Ellensburg Chapter -- Ice Age Floods Institute
Field Trips

Steamboat Rock & Northrup Canyon in the Upper Grand Coulee



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

27-28 April 2019

Preliminaries

Consider joining us for one or both days of hiking and learning in the Upper Grand Coulee's Steamboat Rock State Park on the weekend of April 27-28. With more springtime warming, the wildflowers should be spectacular! And with a bit of luck we should see a fair amount of wildlife–on a recent trip we saw mule deer, song birds, bald eagles, crows, and marmots in the area. Bring your binoculars and camera. Ticks and rattlesnakes will likely be out by then so we will need to be on the lookout for them as well. Make sure to bring lunch and snacks, plenty of water, sturdy hiking shoes or boots, hiking poles, weather-appropriate clothing, and a hat for shade.

Day 1—Steamboat Rock

Saturday 27 April 2019

We will meet at the Steamboat Rock trailhead at 10am. This trailhead is at the north end of the paved road in the main part of Steamboat Rock State Park. This part of the park lies closest to Steamboat Rock and is very near the boat launch. You will need a Discover Pass to park there. From the parking area, we will hike up onto the rock and essentially walk its perimeter with four key stops aimed at the spectacular geography and geology. We will focus on the bedrock (basalt and granite), the Cordilleran Icesheet's impact on the landscape, Ice Age floods that isolated the rock from the surrounding plateau, landslides and rockfall that have shaped the rock since the floods, climate-induced differences in vegetation, and human land use changes since the construction of Grand Coulee Dam. Bruce Bjornstad and Gene Kiver, in their book "On the Trail of the Ice Age Floods: The Northern Reaches", describe this trail as "moderate to difficult". In my view, the difficult parts are the several steep stretches getting to the top–the steepest pitch is a bit of a scramble. It is a ~650 feet climb from the parking lot to the top of the rock but the climbing is interspersed with gentle stretches. Hiking poles are really helpful on the steep stretches. The trails on top of the rock are easy to moderate. The total hiking mileage is a bit over 4 miles and we should be back to our vehicles by 4 or 5 pm. You are welcome to hike with us all day or part of the day.

Tentative Schedule

10:00am	**Depart from Steamboat Rock Trailhead in main part of Steamboat Rock State Park**
10:15	**Stop 1-1: Bedrock Geology, Base of Steamboat Rock**
10:45	**Depart**
11:30	**Stop 1-2: South end of Steamboat Rock**
12:15pm	**Depart**
12:45	**Stop 1-3: South Central Steamboat Rock**
1:15	**Depart**
2:00	**Stop 1-4: North end Steamboat Rock**
2:45	**Depart**
3:15	**Stop 1-5: East side Steamboat Rock**
3:45	**Depart**
4:30	**Arrive in parking lot**

Steamboat Rock State Park

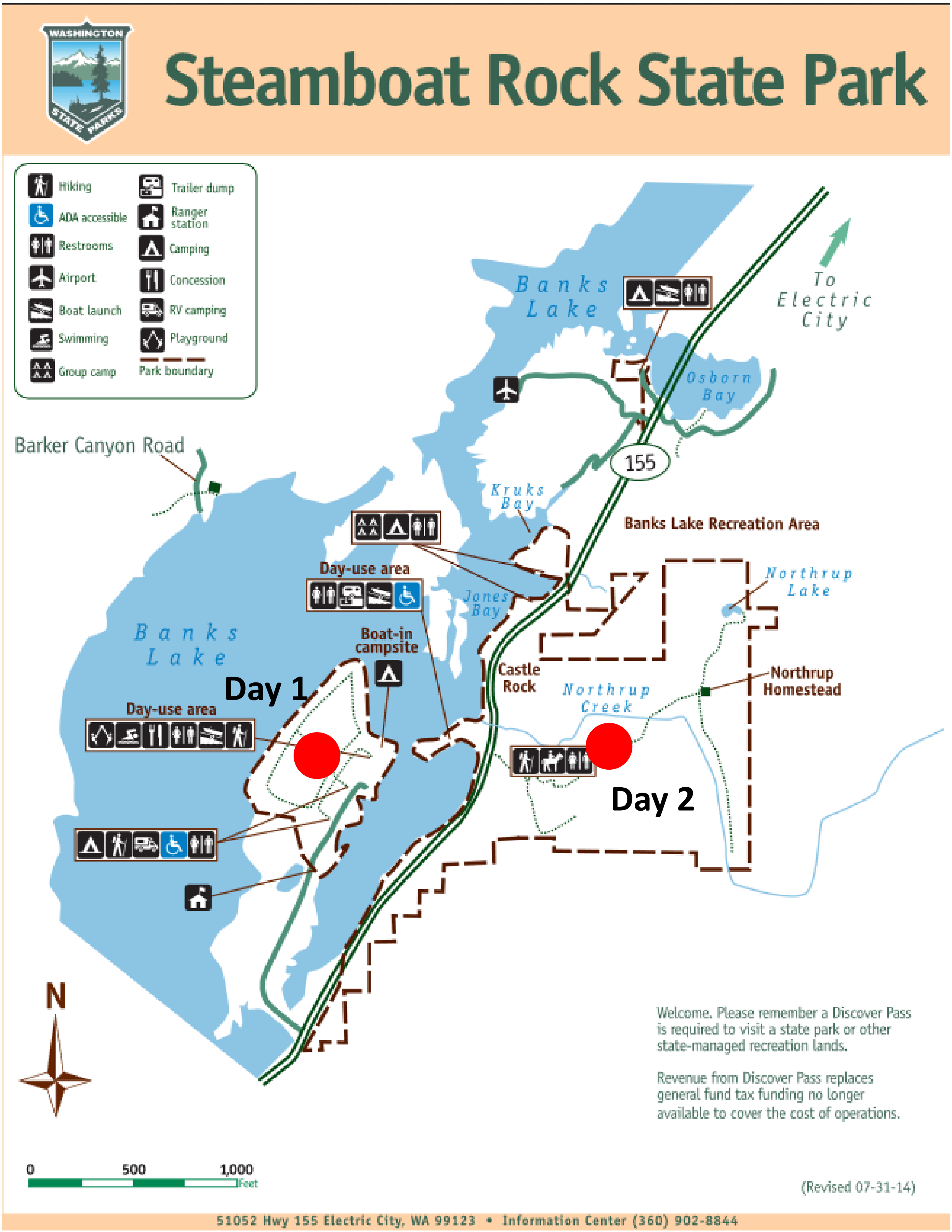


Figure 1-1. Steamboat Rock State Park map. Note general areas of Day 1 and Day 2 field trips. Source: Washington State Parks

Stop 1-1: East Base of Steamboat Rock

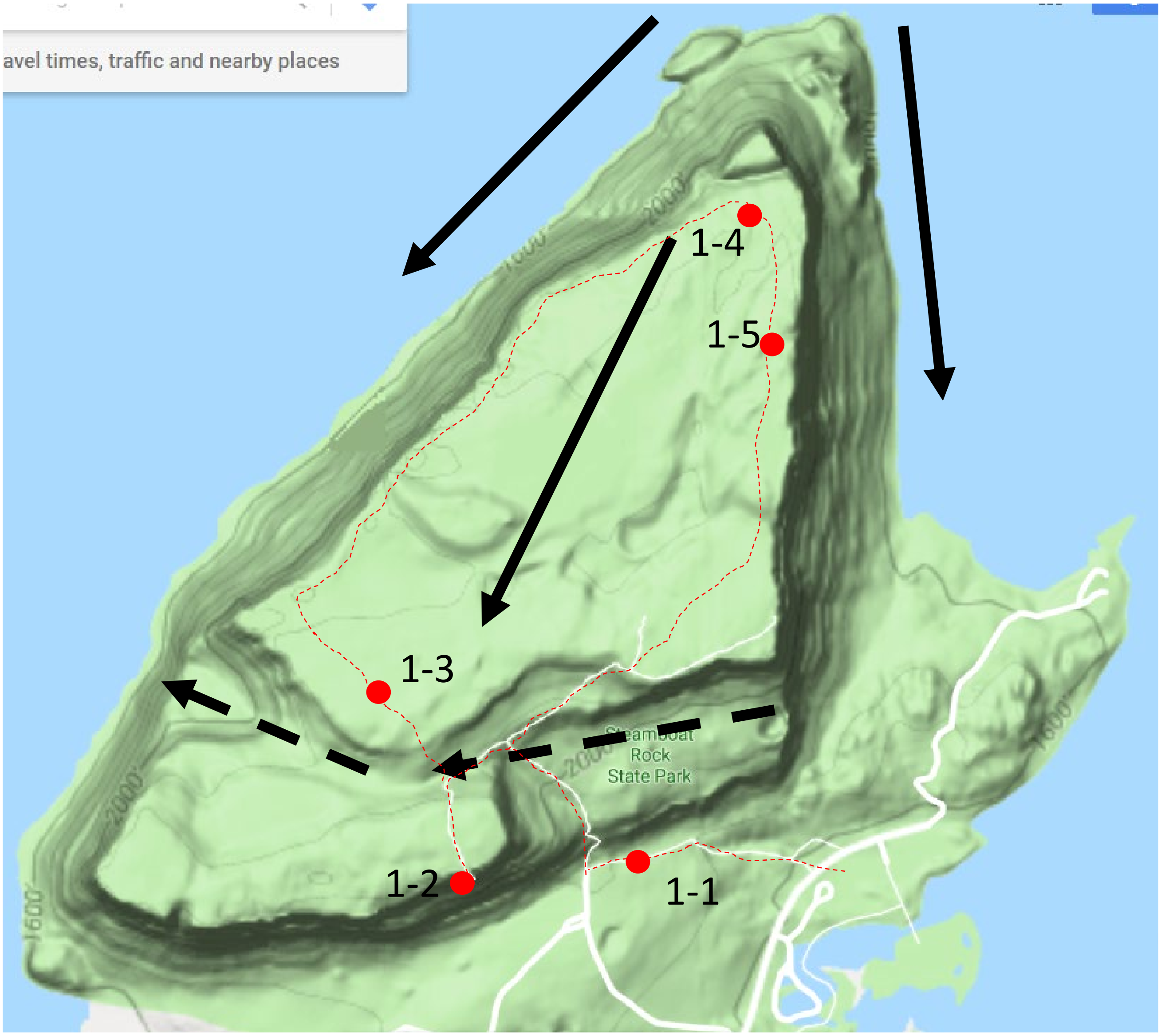


Figure 1-2. Map of Steamboat Rock. Dots & numbers indicate approximate locations of field trip stops. Thin, dashed line is the approximate field trip route. Heavy solid arrows indicate flood flow. Heavy dashed arrows indicate directions of Ice Age flood flow across Steamboat Rock. Entire area is within Steamboat Rock State Park. Source: Google Maps.

Stop 1-1: East Base of Steamboat Rock

Where are we? From the parking lot near the boat launch, we hike up the Steamboat Rock trail to the base of the rock (Figure 1-2) (47.863510°N, 119.129556°W).

What is the cause of the scattered trees here? In short, it is a bit wetter and cooler here than it is to the south. Coulee Dam had an average annual temperature of nearly 50^{o}F and averaged nearly 11 inches of precipitation/year over period 1981-2010 (Figure 1-3). As a comparison, Ephrata averaged 51^{o}F and approximately 8 inches of precipitation/year over the same time period. But it is not as wet and cool as areas north so were are really in a transition zone called an *ecotone* where the shrub steppe vegetation of the south meets the Eastside forest of the north.

What is the bedrock here? Steamboat Rock is composed of *Miocene* Columbia River Basalts overlying older intrusive igneous rocks. We are very near the northern extent of the Columbia River Basalts (Figure 1-4). Still, perhaps 12 different *basalt* lava flows were deposited here between about 15.7-14.5 million years ago (Bjornstad and Kiver, 2012) (Figure 1-5). These include the Grande Ronde (N_2 magnetostratigraphic members) and overlying Wanapum (Roza and Priest Rapids members) (Crosby and Carson, 1999). Geologists differentiate these seemingly identical flows based on their geochemistry and somewhat by their structure. Columbia River Basalt flows typically have an upward sequence of *lower colonnade*, *entabulature*, and *upper colonnade* that reflect the lava cooling patterns (Figure 1-6). Sometimes their bases have *pillows* indicating that lava flowed into water. Their tops are typically *vesicular* (i.e., chock full of gas bubble holes). Each of these sets of colonnade/ entabulature/colonnade give basalt a layered appearance. In addition to the structure of the flows, the generally horizontal layering (i.e., *bedding*) of the basalts here helps define the appearance of Steamboat Rock.

The underlying *intrusive igneous* rocks are *granites*, *granodiorites*, and *diorites* that were emplaced in the *Mesozoic* and early *Cenozoic* (Gulick and Korosec, 1990) (more than ~35 million years ago) as part of a *pluton*. Intrusive igneous rocks cool more slowly than extrusive igneous rocks like basalt; therefore, their texture is more coarse. We will see this texture up close on Day 2 of our field weekend.

The contact between the Columbia River Basalts and the underlying intrusives is an *unconformity*. In this case, the unconformity results from two different types of rock—basalt and granitics—and weathering and erosion of the granitics before the basalt flowed over the surface.

What are these sediments? On our trek up to Stop 1-1, we walked on several different types of sediments. The most common is dune sand. You might be surprised to know that much of the main portion of Steamboat Rock State Park is built atop sand dunes. Beneath that dune sand are rounded gravels ranging from pebbles to boulders in size. These are part of a giant flood bar that trails off the south end of Steamboat Rock. We will talk more about both of these at Stop 1-2.

Stop 1-1: East Base of Steamboat Rock

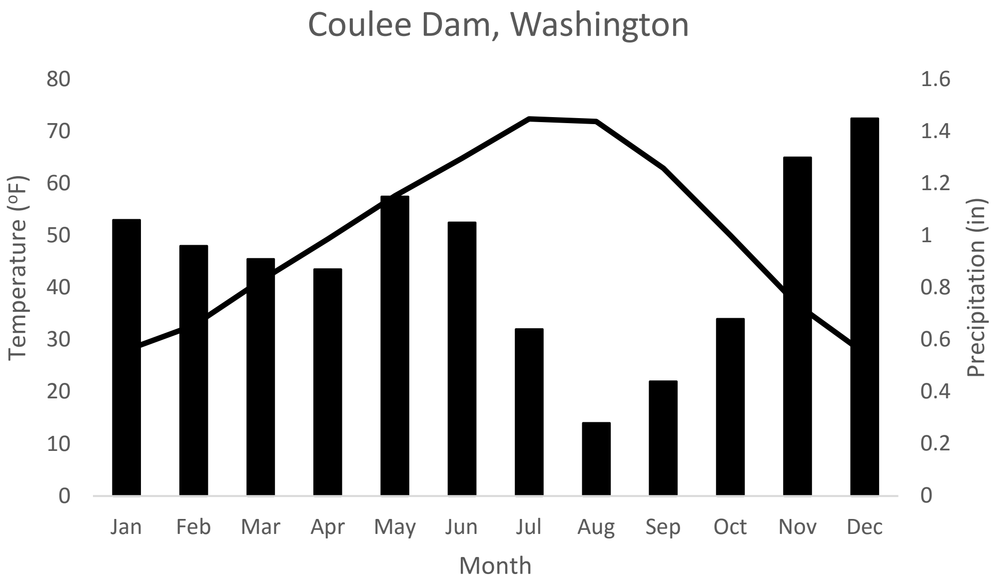


Figure 1-3. Climograph for Coulee Dam for the period 1981-2010. Temperature shown with a line chart and precipitation represented by column chart. Average annual temperature 49.7°F and average annual precipitation 10.8 inches. Source: Western Regional Climate Center.

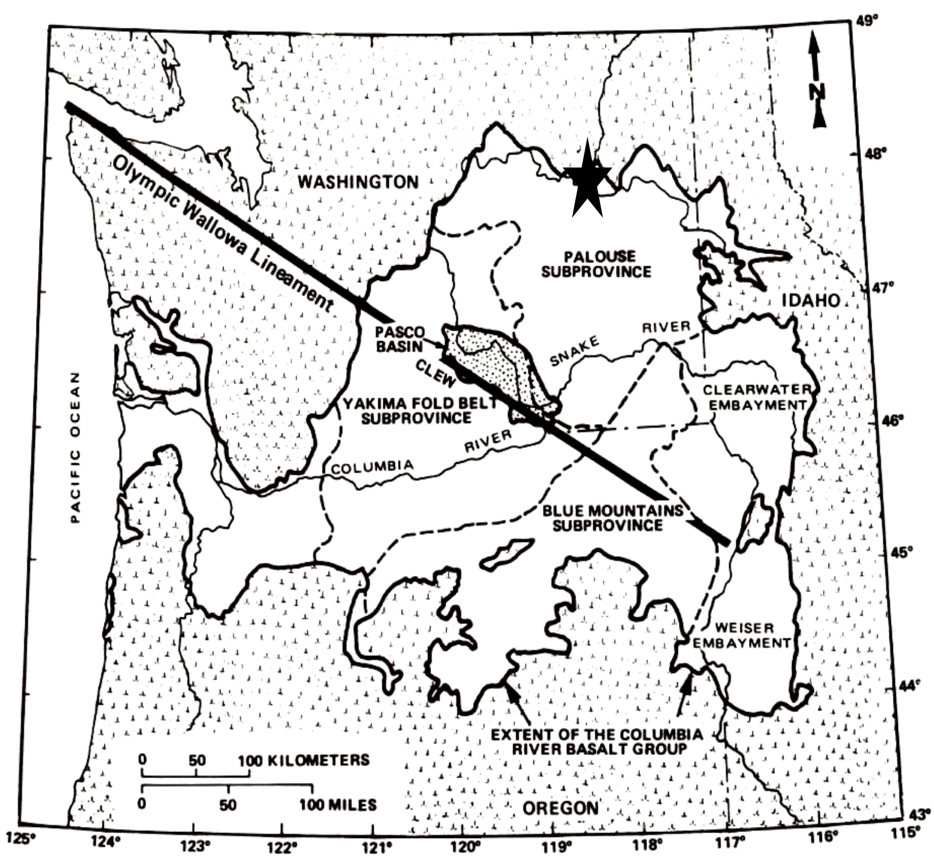


Figure 1-4. The Columbia Plateau and the areal extent of the Columbia River Basalt Group, the four major structural-tectonic subprovinces (the Yakima Fold Belt, Palouse, Blue Mountains, and Clearwater-Weiser embayments), the Pasco Basin, the Olympic-Wallowa lineament. Star indicates approximate location of Steamboat Rock State Park. Source: (Reidel & Campbell, 1989, p. 281).

Stop 1-1: East Base of Steamboat Rock

COLUMBIA RIVER BASALT GROUP FLOWS FOR THE NORTHERN COLUMBIA PLATEAU INCLUDING THE CHANNELED SCABLAND					
Age (mya)	Formation	Member	Number of Flows	Area in Square Miles	Volume in Cubic Miles
6.0	Saddle Mountains	Lower Monumental	1	170	4
8.5		Ice Harbor	4	830	18
		Buford	1	220	5
10.5		Elephant Mountain	2	5,190	105
12.0		Pomona	1	8,710	180
		Esquatzel	1	1,050	17
		Weissenfels Ridge	4	470	5
13.0		Asotin	1	2,490	53
		Wilbur Creek	2	1,190	17
		Umatilla	2	5,830	170
	Total Saddle Mtns		19	11,800	574
14.5	Wanapum	Priest Rapids	3	22,120	670
		Roza	4	15,580	310
15.3		Frenchman Springs	21	26,930	1,540
		Eckler Mountain	8	2,350	41
	Total Wanapum		36	37,050	2,561
15.7-15.6	Grande Ronde	7 members (N2)	33	44,190	6,690
15.9-15.7		4 members (R2)	45	45,450	12,740
16.0-15.9		2 members (N1)	15	39,510	7,530
16.5-16.0		4 members (R1)	27	37,320	8,680
	Total Grande Ronde		120	57,530	35,640
	GRAND TOTAL		*175*	*106,380*	*38,775*

Figure 1-5. Stratigraphy of the Columbia River Basalt Group on the Northern Columbia Plateau. Source: Bjornstad and Kiver, 2012, p. 4.

Why the name? As you approached Steamboat Rock by automobile, what did it remind you of? To many, it reminds them of a ship. One description seems especially appropriate: "*It stands out boldly, alone, isolated, sharply defined against the uncanny scenery with which it is surrounded, split, hewn off from the adjoining county. Although destitute of military masts and turrets, the rock is moulded [sic] into an exceedingly life-like representation of a huge battleship from stem to stern. The sides are perpendicular; the rams at bow and stern incline at an angle of 45 degrees; they have been formed by fallen fragments of disintegrated lava. The lines of demarcation have left main decks, spar decks and gun decks, caused by different flows of lava. Of superstructure there is no trace; nothing but the huge, frowning hull*" (Harry Jefferson Brown in Steele, 1904, p. 594).

Stop 1-1: East Base of Steamboat Rock

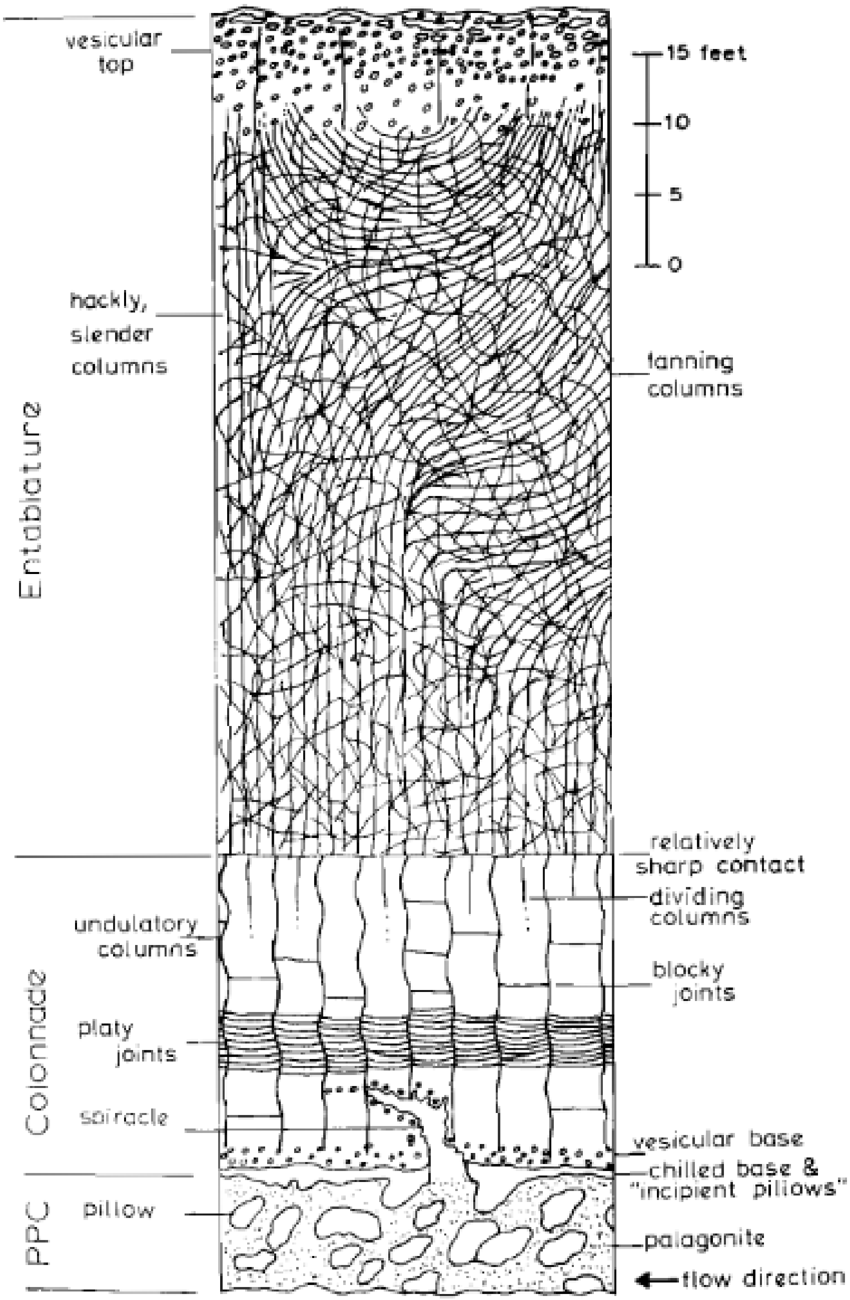


Figure 1-6. Typical cross section of Columbia River Basalt flow. Source: Swanson (1967)

Where to next? As we hike (and scramble) ~0.6 miles up the slopes to Stop 1-2, keep your eyes open for Columbia River Basalt flow features and for sediments other than dune sand and bar gravels. Also, at the sharp bend in the trail at the top of the talus, look for a bit of relatively recent human history—i.e., Steamboat Bill's inscription. Finally, watch where you put your hands and feet as rattlesnakes should be out and about by now.

Stop 1-2: South End of Steamboat Rock

Where are we? We are located on the southeast end of Steamboat Rock (Figure 1-2) (47.863471°, 119.133381°).

Was this area impacted by Ice Age Floods? At various times in the past 2.6 million years, Ice Age floods have raged across Central Washington. The primary floodwater source was Glacial Lake Missoula, a huge ice-dammed lake that backed up the Clark Fork River Valley in northwestern Idaho and Montana Montana. The primary flood paths across Washington were the Cheney-Palouse area, the Crab Creek area, and the Grand Coulee area forming a region collectively called the Channeled Scablands (Figure 1-7). We are standing on a classic scabland surface—i.e., floods have scoured this surface to bare bedrock, and an oddly oriented channel as well as a mesa lie to the north of us on Steamboat Rock. These are all indicators of the *Channeled Scablands*.

What was the origin of the Upper Grand Coulee? From the south end of Steamboat Rock, one can look down much of the entire length of the Upper Grand Coulee. This coulee is the result of a *recessional cataract* (i.e., stepped waterfall) that started where floodwaters crossed the Coulee *Monocline* at approximately right angles, and receded ~13 miles to where we are standing and another 9 miles to the northern end of the Upper Grand Coulee (Figure 1-8). It is difficult to visualize this because the recession occurred primarily in hard basalt bedrock. As Steamboat Falls retreated *headwardly* the Upper Grand Coulee was born. This erosion was enhanced by the columnar jointing in the basalts—i.e., the colonnades were more readily *plucked* than was the entabulature (Figures 1-6 & 1-9). However, when the eroding flows encountered the underlying, less erodible granitic rocks, incision lessened and the coulee broadened from about 1.5 miles to approximately 5 miles (Figure 1-8). J Harlan Bretz (1932) used Niagara Falls and Victoria Falls as current examples of retreating waterfalls to illustrate what happened to create the Upper Grand Coulee and Steamboat Rock. However, the scale of cataract recession in the Upper Grand Coulee is hard to visualize—seven times the width and five times the height of Niagara! Evidence for headward rather than vertical erosion is the presence of the towering, steep coulee walls, the low relief coulee floor, depressions in the coulee floor that are former waterfall *plunge pools*, and h*anging valleys* from tributaries entering the Grand Coulee from the east and west coulee walls (Bretz, 1932; Freeman, 1937). This rapid erosion was further enhanced by a water surface gradient through the area (Figure 1-10).

How did Steamboat Rock form? Steamboat Rock sits about 800 feet above the floor of the Upper Grand Coulee. It measures about 1.4 miles long by 0.6 miles wide. Its basalt top generally matches the composition and elevation of the coulee walls to the east and west. This suggests that it was once part of the a continuous cover of Columbia River Basalts stretching across the area that was subsequently dissected by headward recession of the Upper Grand Coulee (Bretz, 1928). During the headward recession, the channel split leaving behind the Steamboat Rock *monolith* or *goat island*. Perhaps this was a result of the floodwaters encountering the underlying granites and eroding a wider channel. Not only did floodwaters flow around Steamboat Rock, they also flowed over the top forming scablands (Bretz, 1933) and attaining depths of as much as 200 feet above the top of Steamboat Rock (Bjornstad and Kiver, 2012).

Stop 1-2: South End of Steamboat Rock

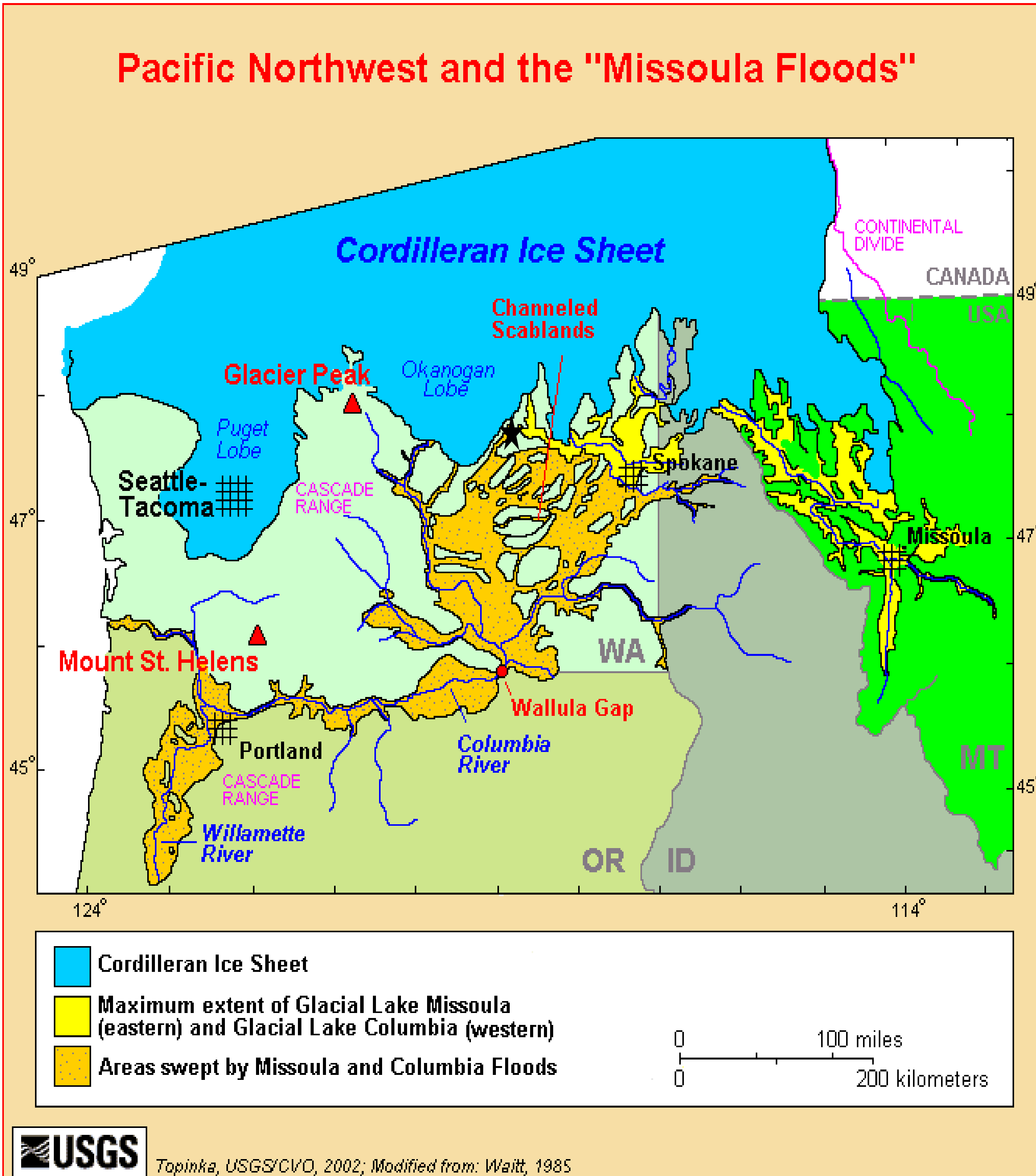


Figure 1-7. Map of the late Pleistocene Cordilleran Icesheet and Missoula Floods in the Pacific Northwest. Star indicates location of the town of Grand Coulee. Source: Cascade Volcano Observatory website.

Stop 1-2: South End of Steamboat Rock

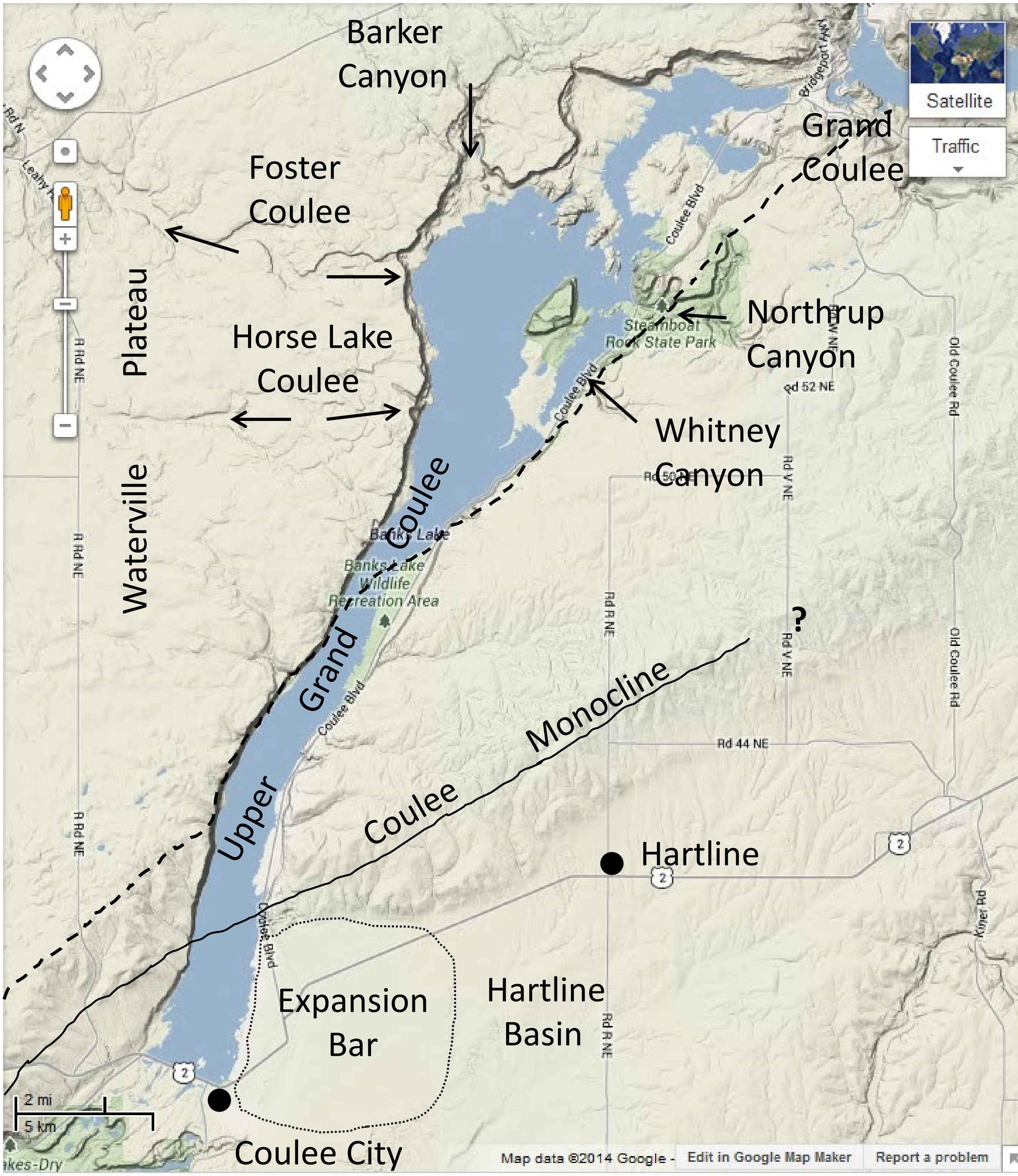


Figure 1-8. Topography of the Upper Grand Coulee and vicinity. Solid line indicates approximate position of Coulee Monocline. Dashed line represents the approximate (actual & inferred) position of the Withrow Moraine. Dotted line outlines a large expansion bar. Source: Google Maps + glacial boundary from Kovanen and Slaymaker (2004).

Stop 1-2: South End of Steamboat Rock

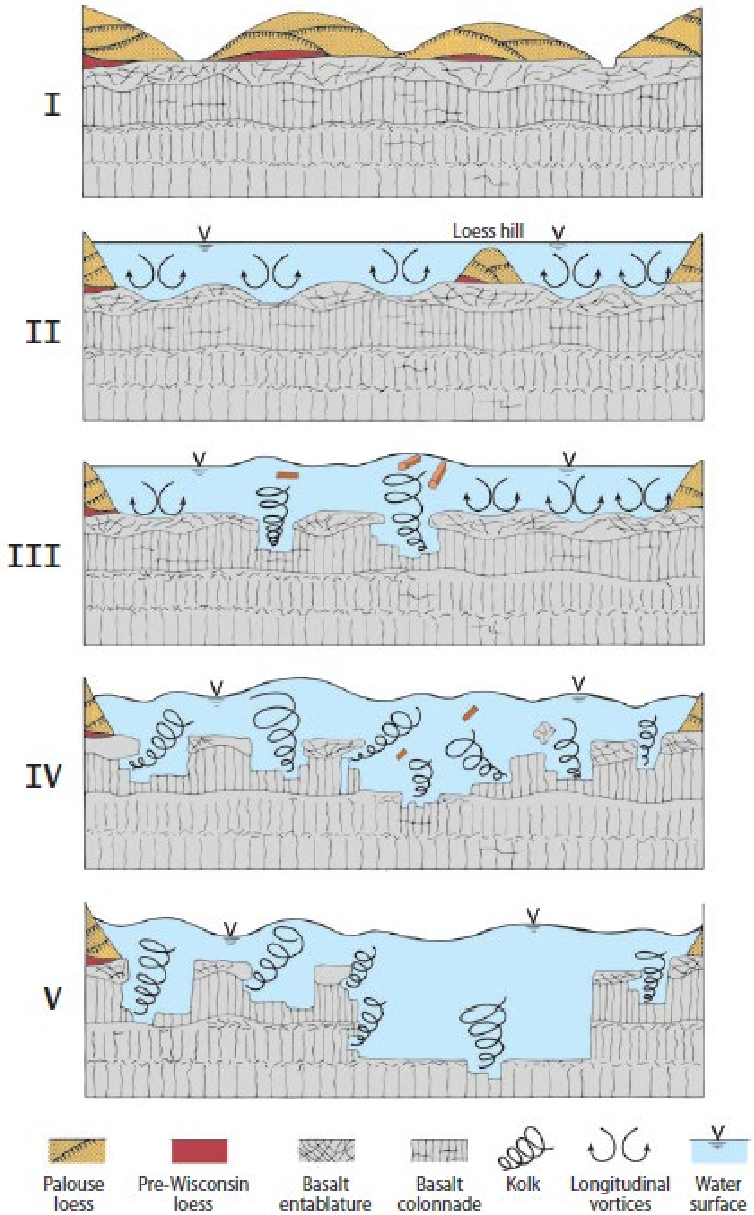


Figure 1-9. Inferred sequence of erosion for Channeled Scabland. Source: Baker (2009).

Stop 1-2: South End of Steamboat Rock

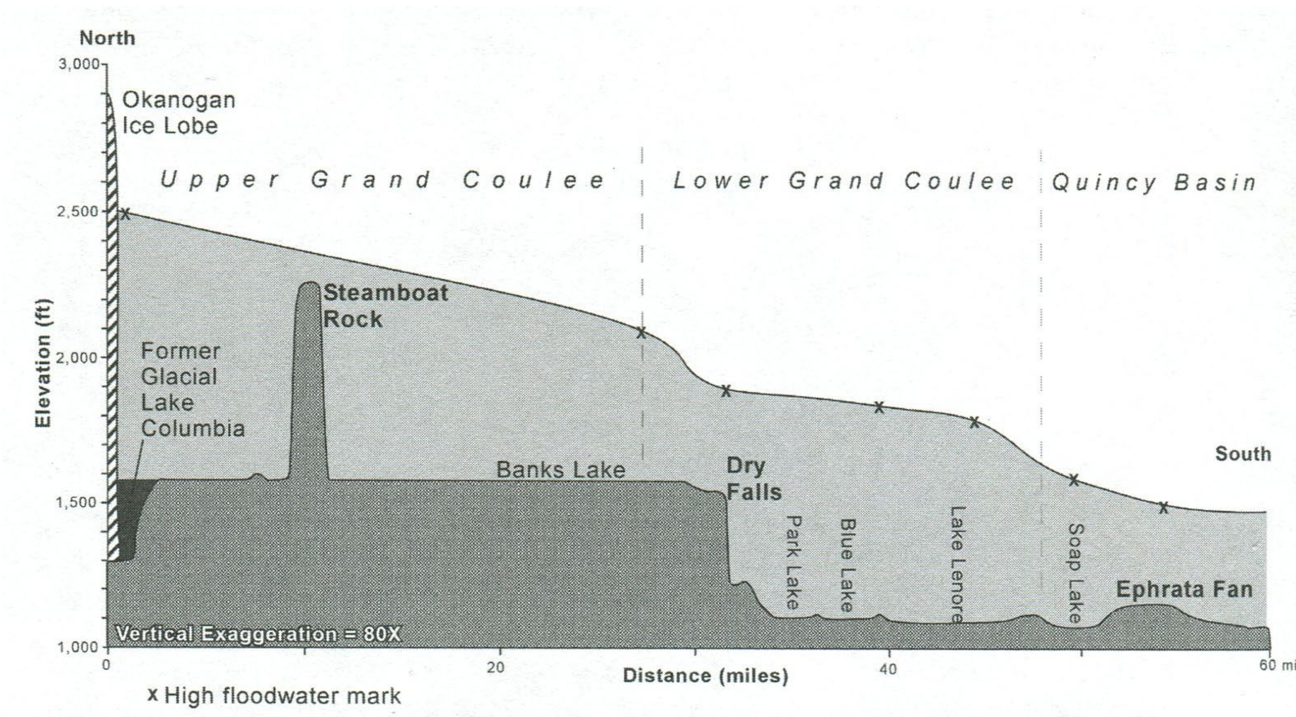


Figure 1-10. Maximum flood surface profile in the Grand Coulee. Note that the maximum depth of floods was nearly 1,000 feet deep, and that, at this maximum, floodwaters would have been approximately 200 feet over our heads here atop Steamboat Rock! Source: Bjornstad and Kiver (2012, p. 109).

What's the source of the large boulders? Large, granite boulders are common on Steamboat Rock. Previous researchers (e.g., Freeman, 1937) have argued they were deposited by glacial ice, particularly the Okanogan Lobe of the Cordilleran Icesheet. The maximum southeastern extent of this lobe is at least here (Bretz, 1932) and may be as far east as the headwaters of Northrup Canyon (Gulick and Korosec (1990) (Figure 1-8). This means that the Okanogan Lobe once covered this surface. That makes this large granite boulder an *erratic*, a rock that is out of place because a glacier deposited it here. Erratics, striations, and moraines support the hypothesis that a glacier was once here. Large granitic boulders atop Steamboat Rock have previously been cited as evidence of glacial deposition rather than Ice Age flooding here (Freeman, 1937; Crosby and Carson, 1999). Their reasoning is that floodwaters would have deposited basalt erratics stripped the heavily jointed basalt flows. Further, floodwaters flowing over the top of Steamboat Rock would have been moving too fast to deposit large boulders; therefore the large erratics here are likely glacially deposited (Bjornstad and Kiver, 2012). Striations bearing S 20 E (or 160^{o}) are present on the extreme southern end of Steamboat Rock (Bretz, 1932; Freeman, 1937). A brief reconnaissance of the area on a partially snow-covered surface in March 2019 did not reveal these striations. However, I have seen glacial striations on the basalts around the southwestern base of Steamboat Rock (Figure 1-13). We will speak more of these later.

Stop 1-2: South End of Steamboat Rock

Figure 1-11. Large, granitic boulder on south end of Steamboat Rock. Nancy Lillquist (5’3” tall) for scale. Source: Karl Lillquist, March 2019.

Figure 1-12. Glacially polished and striated basalt near southwest base of Steamboat Rock. Note Glacial Lake Columbia sediments atop basalt. Source: Karl Lillquist, September 2014.

Stop 1-2: South End of Steamboat Rock

What is the low surface to the south? The large, slightly raised surface stretching out to the south of Steamboat Rock is a *pendant bar*. Bars form at the base of water flows as velocity decreases. They typically have blunt upvalley "heads" and long, tapering downvalley "tails". Their surfaces slope downvalley. Some have described their forms as "whalebacks", a shape very different from a dissected terrace, a form those favoring a non-catastrophic origin for the *Channeled Scablands* would have preferred finding in these areas. They are composed of well to poorly sorted and bedded gravels and sands. The situation in which velocity decreases determines the type of bar (Figure 1-13): 1) c*rescent bars* form on the inside bends of channels; 2) *longitudinal bars* form in mid-channel or along channel walls; 3) e*xpansion bars* form where channels widen abruptly; 4) *pendant bars* form downcurrent of mid-valley obstacle or valley-wall spurs on bends; 5) *eddy bars* form in valleys at the mouths of tributaries; and 6) *delta bars* form where floodwaters on a high surface adjacent and parallel to a main channel encounter a transverse tributary valley. As noted earlier, bars are often differentiated from adjacent bedrock by not only their shapes but also by their vegetation cover—i.e.., typically bars are more vegetated or vegetated with more grass than is adjacent bedrock.

Dunes…here? Look closely at the surface of the longitudinal bar. Can you see that the surface is not smooth? Rather, crescent-shaped features adorn the bar. These are *parabolic dunes* whose crescent-shapes have upwind "arms" that are typically anchored with vegetation (Figures 1-14, 1-15 & 1-16). The central part is often a "blowout" of exposed sand. As the blowout enlarges downwind, the vegetation anchored arms trail on the sides. Over time, multiple parabolic dunes may follow the same path resulting in a series of "nested" dunes. These are dunes of semi-arid areas as they require vegetation for their formation. They also indicate unidirectional winds (Ritter and others, 2011). The parabolic dunes south and east of Steamboat Rock likely formed from the pendant bar sands and perhaps coarser sediments of Glacial Lake Columbia (we will talk about this later). Their forms indicate they resulted from southwest to west winds.

What's that pattern? One of the results of floodwaters stripping the soils from the top of this part of Steamboat Rock is that we get a view of the underlying geology. On the southwest end of Steamboat Rock, large, biscuit-shaped *patterned ground* is present (Figure 1-17). As is often the case with large, subtle features, they are best viewed from above. What caused this patterned ground? It seems most likely that it reflects a large *jointing* pattern (i.e, mega joints) in the underlying basalt flows. These large joints are more easily weathered and eroded than the surrounding rock therefore they show up as lower areas on the landscape. When they intersect the abrupt edge of the basalt they result in the common *scallops* we see here and on other basalt edges in the region. The take home message is that mega joints play a key role in shaping abrupt basalt edges and were likely exploited by Ice Age floods.

Where to next? From here, we will retrace our route to the large transverse channel, then ascend the north wall of that channel to another viewpoint near the center of the rock. The total distance of this leg of the hike is about 0.3 miles.

Stop 1-2: South End of Steamboat Rock

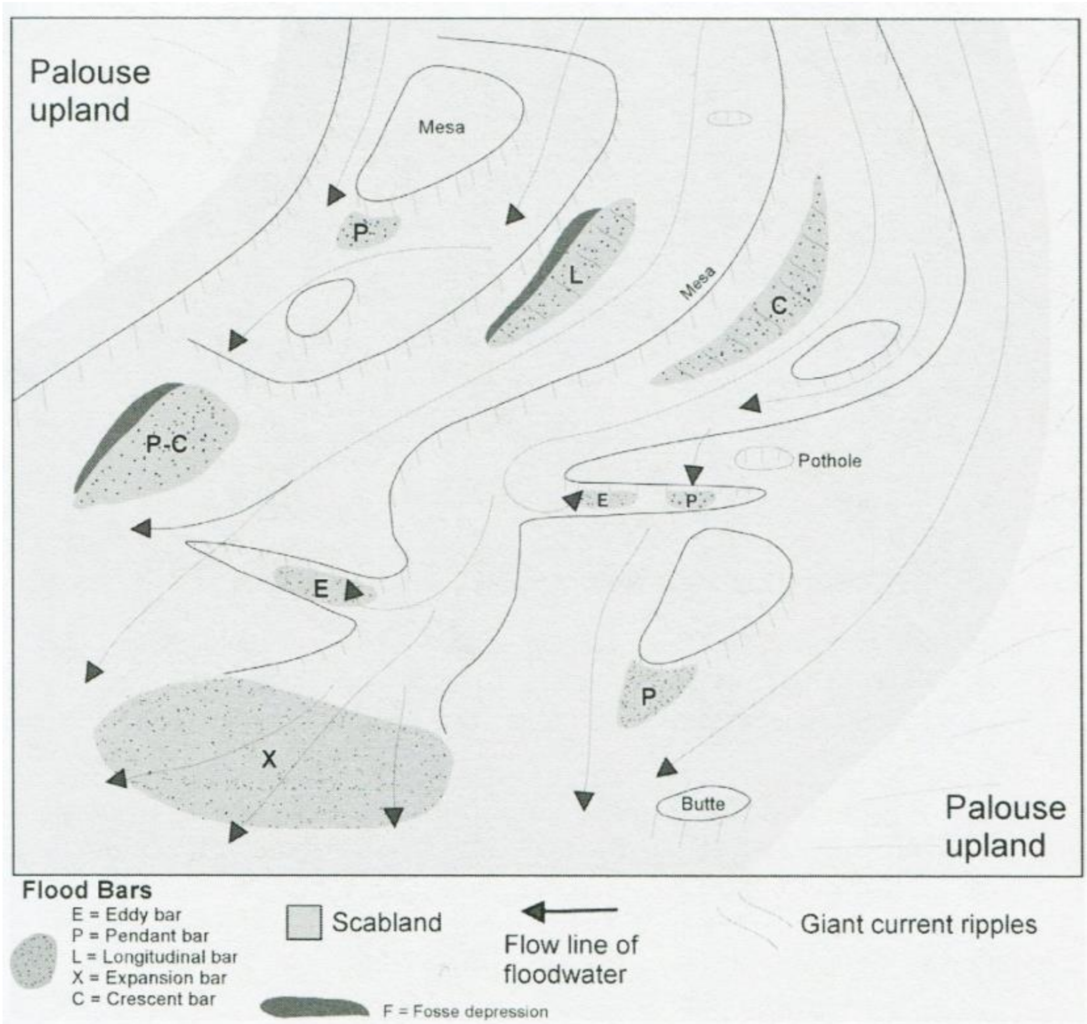


Figure 1-14. Types of flood bars. Source: Bjornstad and Kiver (2012, p. 51).

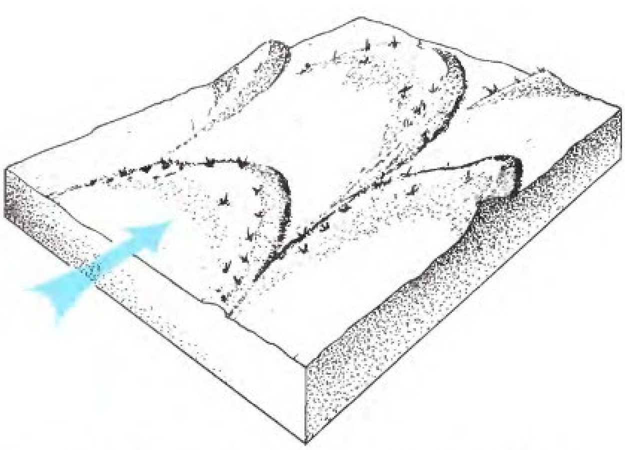


Figure 1-13. Parabolic dunes. Source: McKee (1979, p. 12).

Stop 1-2: South End of Steamboat Rock

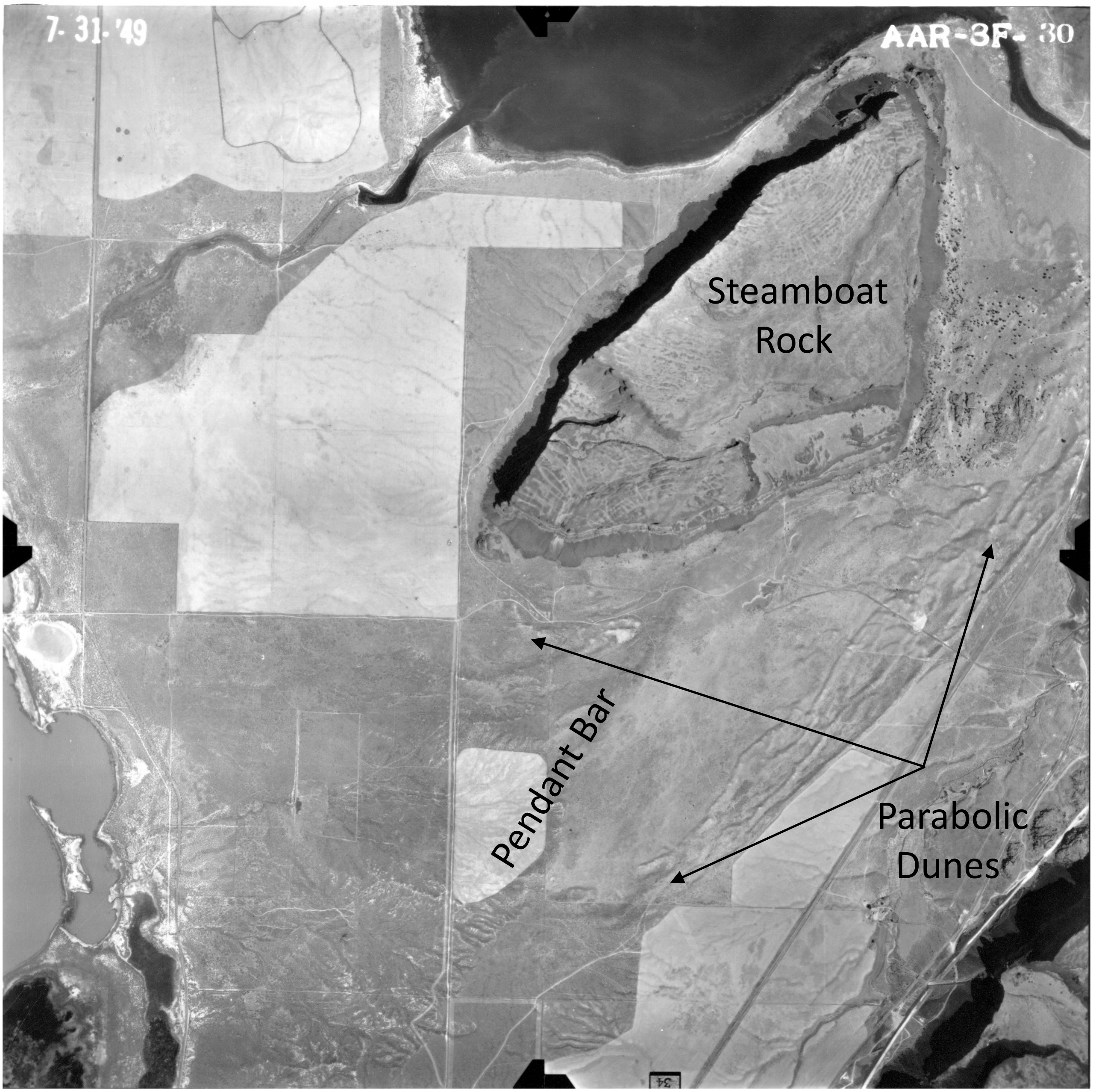


Figure 1-14. Vertical aerial view of Steamboat Rock, large pendant bar, and parabolic dunes. Dunes draped across the pendant bar indicate they post-date Ice Age floods. Dunes indicate predominantly southwest to west winds. Source: USDA Production and Marketing Administration aerial photograph AAR-3F-30, dated July 31, 1949. Accessed on Central Washington Historical Aerial Photograph Project website: (http://www.gis.cwu.edu/geog/historical_airphotos/).

Stop 1-2: South End of Steamboat Rock

Figure 1-16. Postcard view of southeast side of Steamboat Rock, likely from the 1940's. Note the sandy conditions where the farm buildings are located. Banks Lake now covers this site. Source: https://picclick.com/Real-photo-postcard-RPPC-Steamboat-Rock-Grand-Coulee-273737728773.html various internet vendors.

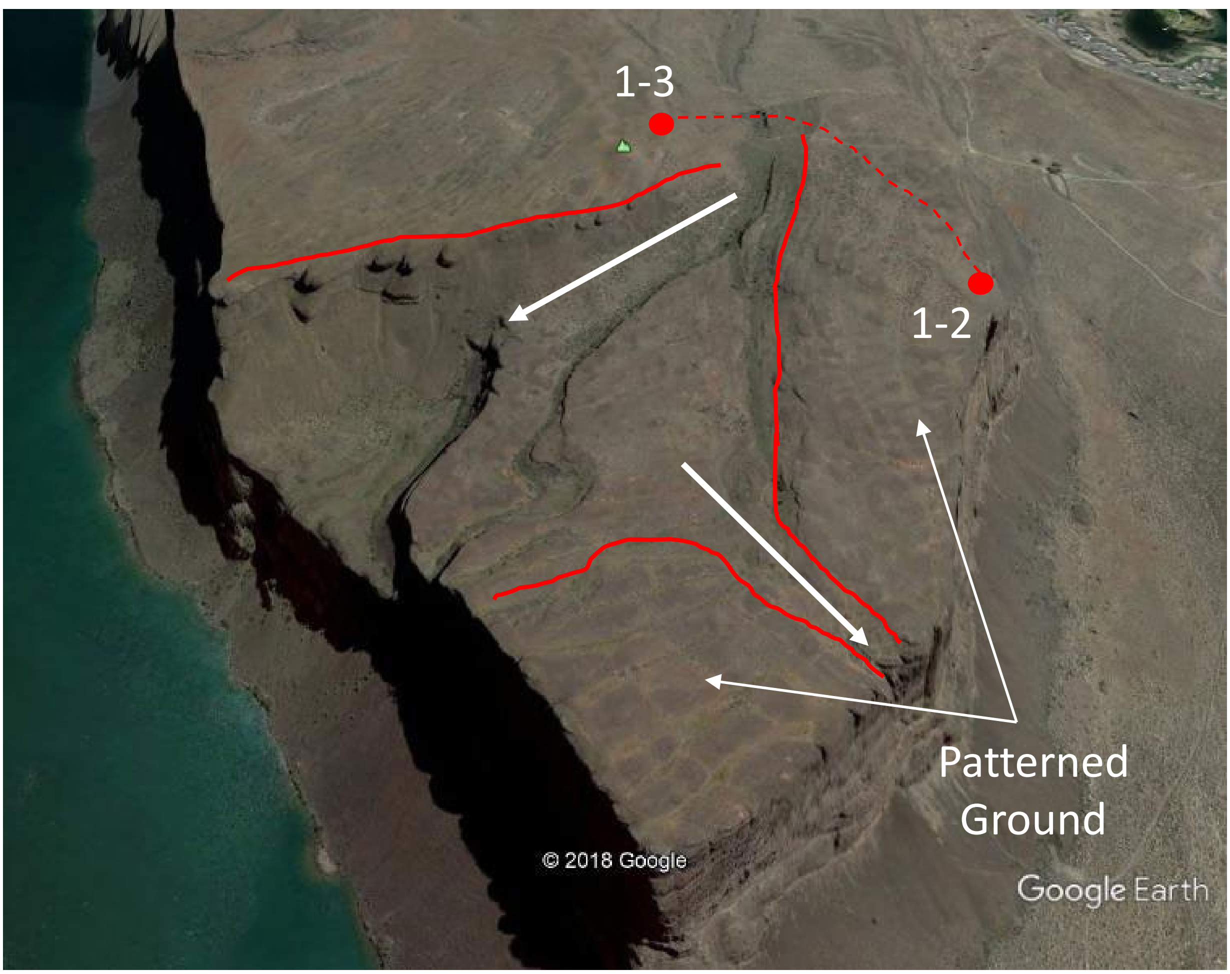


Figure 1-17. Vertical aerial view of intersecting joints and resulting patterned ground in basalts atop the south end of Steamboat Rock. Red solid line represents transverse channel. White arrows are Ice Age flood flow directions. Red dots and numbers indicate field trip stops. Red dashed line is the approximate route from Stop 1-2 to 1-3. Source: Google Earth.

Stop 1-3: Central Steamboat Rock

Where are we? We are located on a high spot just north of the transverse channel near the center of Steamboat Rock (Figure 1-2) (47.866325°N, 119.135484°).

How did this channel form? The ~linear, steep-walled nature of the landform suggests it formed from river (or *fluvial*) erosion (Figures 1-17 & 1-18). It features two outlets from the rock—one to the southwest and one to the west. The larger and lower nature of the western one suggests it carried more water and did so later in the evolution of Steamboat Rock. Bjornstad and Kiver (2012) refer to this as a "hanging coulee" because its southwest end is left hanging above the Upper Grand Coulee floor (Figure 1-19). This suggests that much Upper Grand Coulee incision took place after the formation of this channel. The incision of this feature resulted in at least three terraces that represent the tops of different lava flows (we call these *stripped structural surfaces*) in this western channel.

A key question here is what river formed this feature? Some have argued that it represents a pre-Ice Age Flood river or stream that survived the Ice Age floods (Freeman, 1937). Others suggest it is a coulee formed as Ice Age floodwaters exploited weaknesses in the basalts (Crosby and Carson, 1999). It very well could be both—i.e., an Ice Age flood that exploited a pre-existing channel. If it was a pre-existing channel, what did it originally connect to? The western outlet suggests that it may align with Foster Creek on the west side of the Upper Grand Coulee (Bjornstad and Kiver, 2012) (Figure 1-20).

What are these ridges? We are standing atop a subtle but significant ridge of sediment as a opposed to the bedrock and shallow soil we were on at Stop 1-2. This sediment is a jumble of different sizes of material. The ridge is sinuous like a snake and in places hummocky. All of this evidence points to the feature being one of several end moraines deposited by the Okanogan Lobe as it retreated from its terminal position east and south of here. These moraines are notably absent from the south end of Steamboat Rock. Several researchers have mentioned the Steamboat Rock moraines (Freeman, 1937; Crosby and Carson, 1999; Bjornstad and Kiver, 2012). Crosby and Carson (1999) note two different sets of moraines on the rock. I see five different moraines on Google Earth (Figure 1-21)—I will bet there are more. Each moraine ridge represents a time when the Okanogan Lobe paused as it melted back. Keep your eyes open for the rest of the day and you will see these as well as large granitic erratics (Figure 1-11) scattered about the top of the rock.

When was Steamboat Rock glaciated? According to Richmond and others (1965), the Okanogan Lobe advanced south at least twice to terminate on the Waterville Plateau. In my extensive kicking around on the Waterville Plateau, I have yet to find the evidence of an earlier glaciation. In the Upper Grand Coulee, only evidence of the most recent advance of the Okanogan Lobe has been identified. So when did this most recent glaciation occur? Two of the large granitic erratics dated with the ^{36}Cl method of surface exposure dating have ages of 16,280 and 13,190 years before present. These dates probably represent the advance of the Okanogan Lobe to this location (Baker and others, 2016). Given evidence presented later, the older of the dates--~16,280—is likely a more realistic age for the advance while the moraines discussed above are slightly younger.

Was the Upper Grand Coulee here when the last glaciation occurred? The short answer is yes. Several pieces of evidence support this. Bretz (1923, 1932) noted that the northwest sides of granite knobs on the floor of the Upper Grand Coulee north of Steamboat Rock (we will see these from stop 1-4) are rounded, smoothed, and in some cases, striated or grooved. Rocks in Barker Canyon (Figure 1-20) were polished, rounded, and grooved by glacial ice (Freeman, 1937). And as noted earlier, striations and glacially polished basalts exist near the southwest base of Steamboat Rock (Figure 1-12).

Stop 1-3: Central Steamboat Rock

Figure 1-18. Traverse channel on the southern part of Steamboat Rock. View toward west. Source: Karl Lillquist, March 2014.

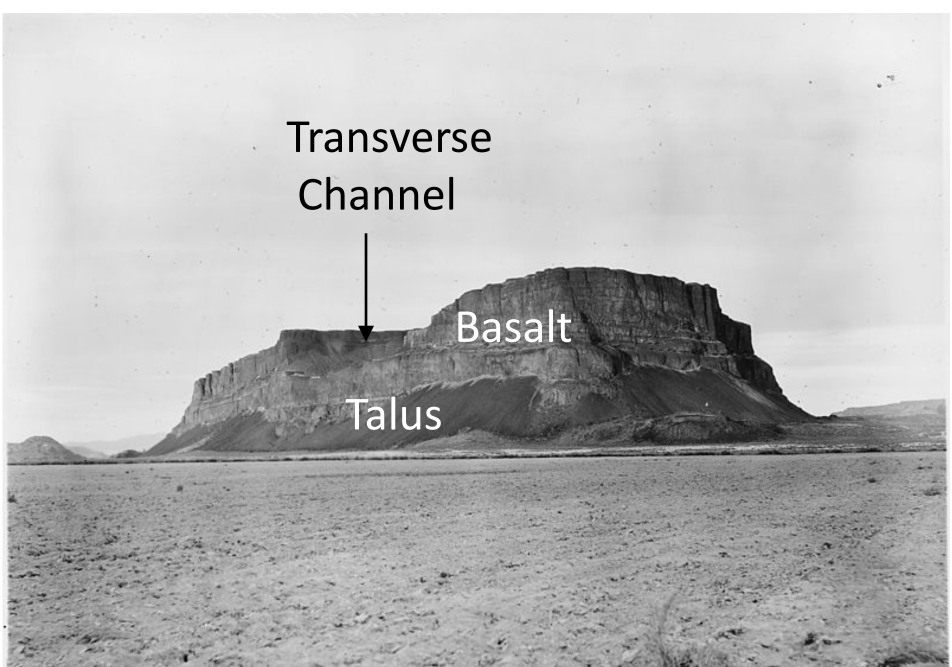


Figure 1-19. View of the west and south sides of Steamboat Rock from the area now covered by Banks Lake. Note the talus apron below the basalt bedrock. Also, see the hanging transverse channel and the cultivated field in the foreground. Source: Unknown photographer, September 1935, Record Group 115, National Archives Identifier 294040, National Archives.

Stop 1-3: Central Steamboat Rock

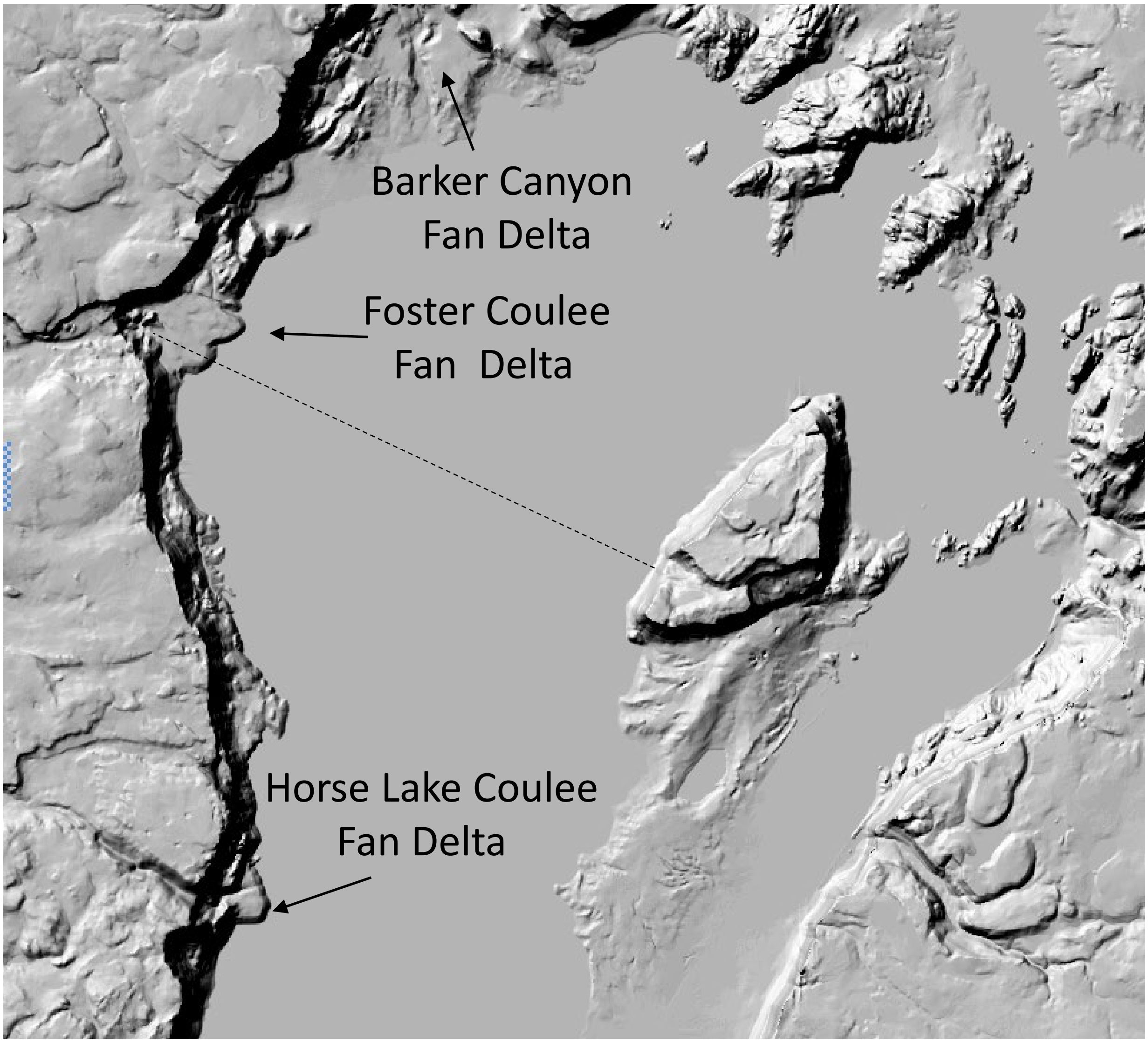


Figure 1-20. Shaded relief map of Steamboat Rock in relation to Foster Creek. Dashed line represents the possible alignment between the transverse channel atop Steamboat Rock with Foster Creek. Source: Caltopo.

What are the those terrace-like features on Banks Lakes' west shore? Two large drainages are present in the west wall of the Upper Grand Coulee (Figures 1-8 & 1-20). Both were west-flowing streams that may have transported Ice Age floods to the west before the formation of the Upper Grand Coulee. In fact, floodwaters transported by these channels may have been the water supplies for the floods that descended Moses Coulee, the topic of our early Fall 2018 IAFI-Ellensburg field trip. The floods likely truncated the heads of these streams leaving them hanging on the edge of the Upper Grand Coulee. What is odd about the channels is that their upper portions reversed directions and dumped glacial meltwater into the Upper Grand Coulee after it was formed as indicated by the huge fan deltas (or delta bars) formed at their mouths in the coulee (Figure 1-20) (Bretz, 1932).

Where to next? From Stop 1-3, we will continue west to the western edge of Steamboat Rock, then follow this edge north to the northern tip. Total mileage is about 1.3 miles.

Stop 1-3: Central Steamboat Rock

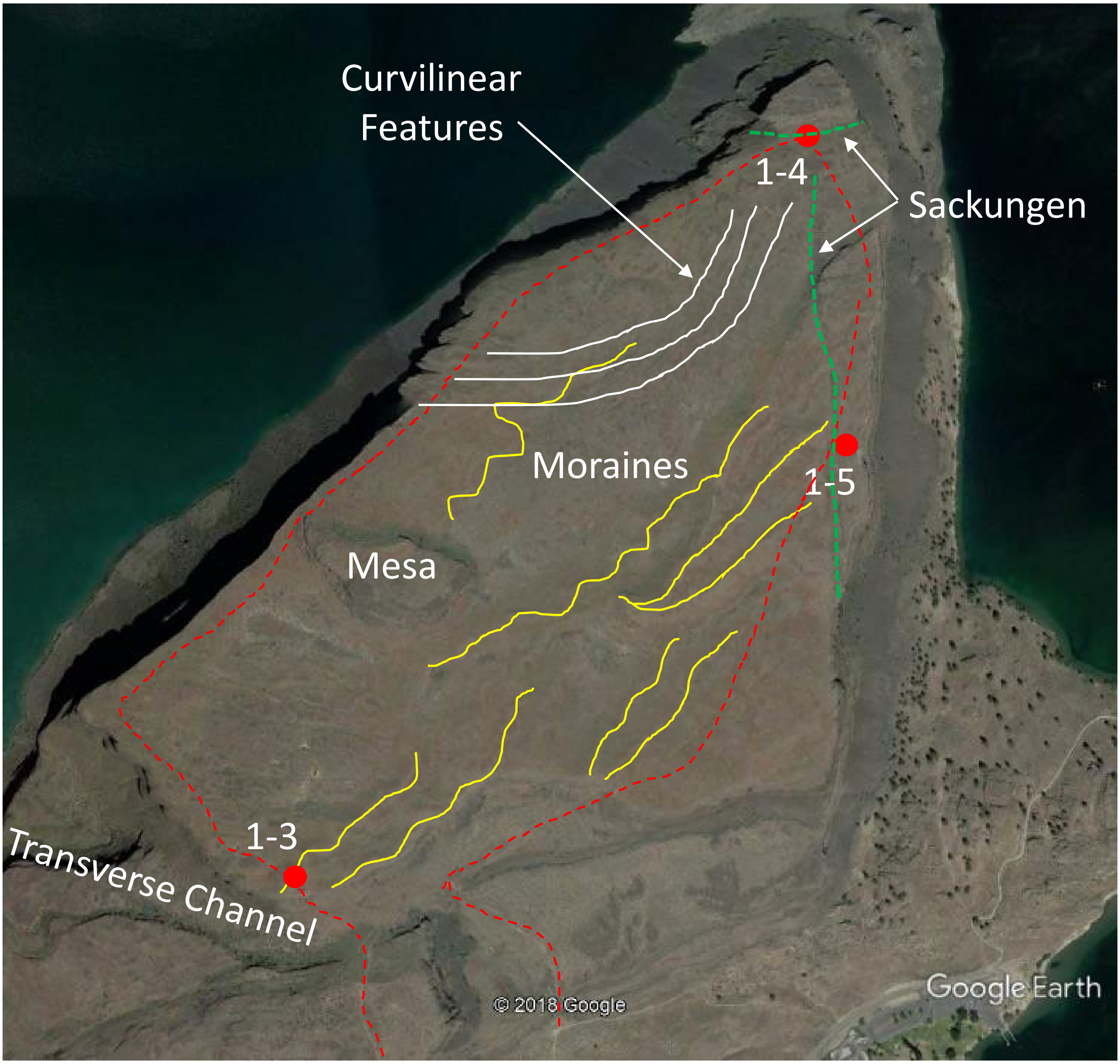


Figure 1-21. Recessional end moraine remnants (yellow lines) atop the northern two thirds of Steamboat Rock. Green dotted line represents sackungen. Approximate locations of field trip stops are shown with red dots and numbers. Approximate route around the rock is shown with red dashed line. Source: Google Earth.

Stop 1-4: North End of Steamboat Rock

Where are we? We are located near the the north tip or "prow" of Steamboat Rock (Figure 1-2) (47.877473°N, 119.123827°W).

What are the rounded rock outcrops in Banks Lake? The rounded bedrock knobs are granitic rocks that are well older than the overlying Columbia River Basalts. Bjornstad and Kiver (2012) refer to them as "the Banks Lake *inselbergs*" (Figure 1-22). These granitic rocks were weathered and eroded prior to being covered by the Columbia River Basalts. Ice Age flood and glacial erosion, and post-Ice Age weathering further rounded these outcrops to their present state. We will discuss granite weathering in more detail at Northrup Canyon.

What is the large gap in the coulee wall to our northeast? As Steamboat Falls continued to migrate upstream of Steamboat Rock, it eventually eroded through the uplands separating the Upper Grand Coulee from the Columbia River Valley. The gap is where the final erosion occurred (Figure 1-22). Once the lowering of this divide occurred, the Upper Grand Coulee became the lowest outlet of the three scabland tracts (i.e., Cheney-Palouse, Crab Creek, and Grand Coulee); therefore, the Grand Coulee became the primary route of Missoula Floods. This gap also allowed an arm of Glacial Lake Columbia, a lake impounded behind the Okanogan Lobe of the Cordilleran Icesheet, to occupy the Upper Grand Coulee up to about 1,540 feet elevation. This lake stretched to near Coulee City where it was either impounded by the large Coulee City expansion bar (Bjornstad and Kiver, 2012) or by a bedrock sill near present-day Coulee (implied by Waitt, 1994). This sill might have been enhanced by isostatic depression at the north end of the Upper Grand Coulee . Waitt (1994) notes about 90 feet of subsequent isostatic rebound in the Upper Grand Coulee. Late floods through the Upper Grand Coulee were smaller (but still significant) (Atwater, 1987). Because their sediments lie stratigraphically below Glacial Lake Columbia sediments to the south of Steamboat Rock, it appears that Ice Age flooding ended well before the demise of Glacial Lake Columbia.

Have landslides occurred here? As a near vertical sided, towering feature composed of bedded and jointed basalt, Steamboat Rock is very prone to *mass wasting* (e.g., landslides) This has occurred here primarily as *rockfall* that results in the *talus* that rings the rock (Figure 1-19). A large *rotational slide* has also occurred *on the* north end of the rock creating a large backtilted block (Figure 1-23). Given their locations on the walls of Steamboat Rock, the talus apron and the rotational slide all formed after the last major Ice Age floods.

A third form of mass wasting (actually a group of mass wasting types) is also occurring on the margins of Steamboat Rock—*sackung* (or *sags*). A sackung is very slow, large, deep-seated rock flow driven by gravity in stratified or densely jointed, homogenous rocks (Bisci and others, 1996). Sometimes, these are called deep-seated gravitation slope deformations (Agliardi and others, 2012). *Sackungen* may include slide, flow, and spread depending on the degree of plastic deformation <u>within</u> the bedrock. They often occur on the summits and steep slopes of mountain ridges (Cruden and Varnes, 1996). Sackungen are recognized by their *graben*-like depressions, double ridges, *scarps*, and summit lakes on the upslope portions of these features, counterscarps on their middle slopes, and bulges, buckled folds, and fractured rock masses on their lower slopes (Figure 1-24) (Bisci and others, 1996; Cruden and Varnes, 1996; Agliardi and others, 2012). Sackung development requires sufficiently high slopes to cause gravitational stresses and rock that is resistant enough to remain stable (Bisci and others, 1996). The edges of Steamboat Rock, as well as other coulee walls within the Channeled Scablands, are ideal places to develop sackungen. Numerous sackungen are present on Steamboat Rock, especially nearer the north end (Figures 1-21 & 1-25).

Stop 1-4: North End of Steamboat Rock

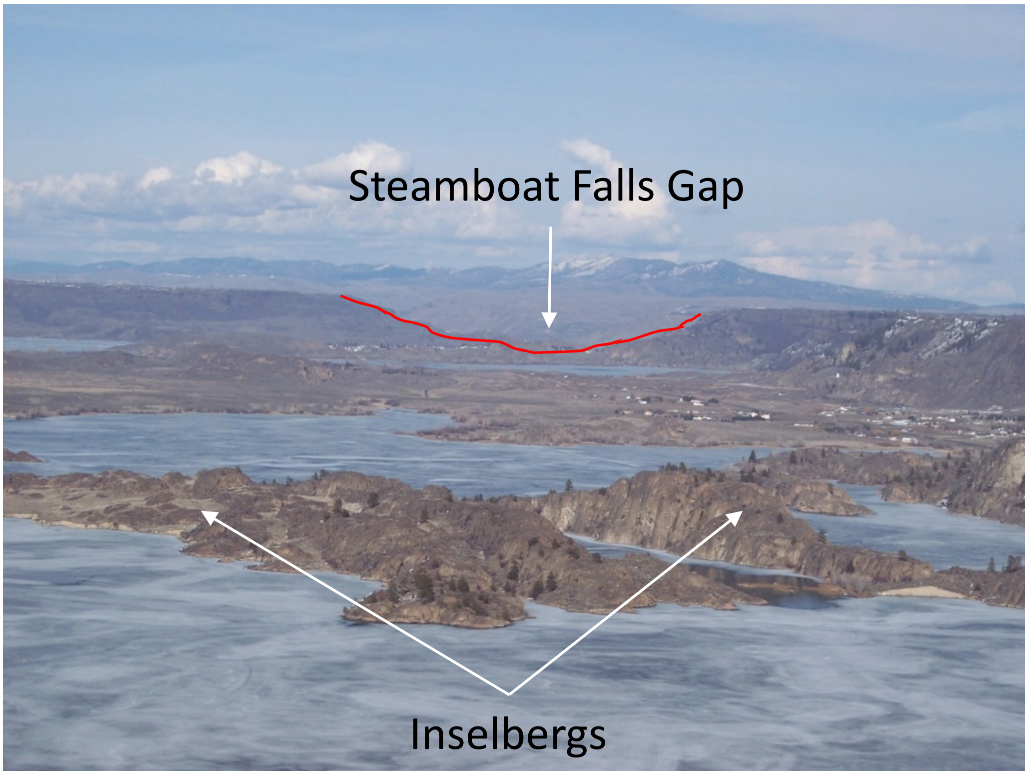


Figure 1-22. Rounded, granitic "inselbergs" of a frozen northern Banks Lake. Note the gap where Steamboat Falls headwardly eroded into the Columbia River valley. Source: Karl Lillquist, March 2019.

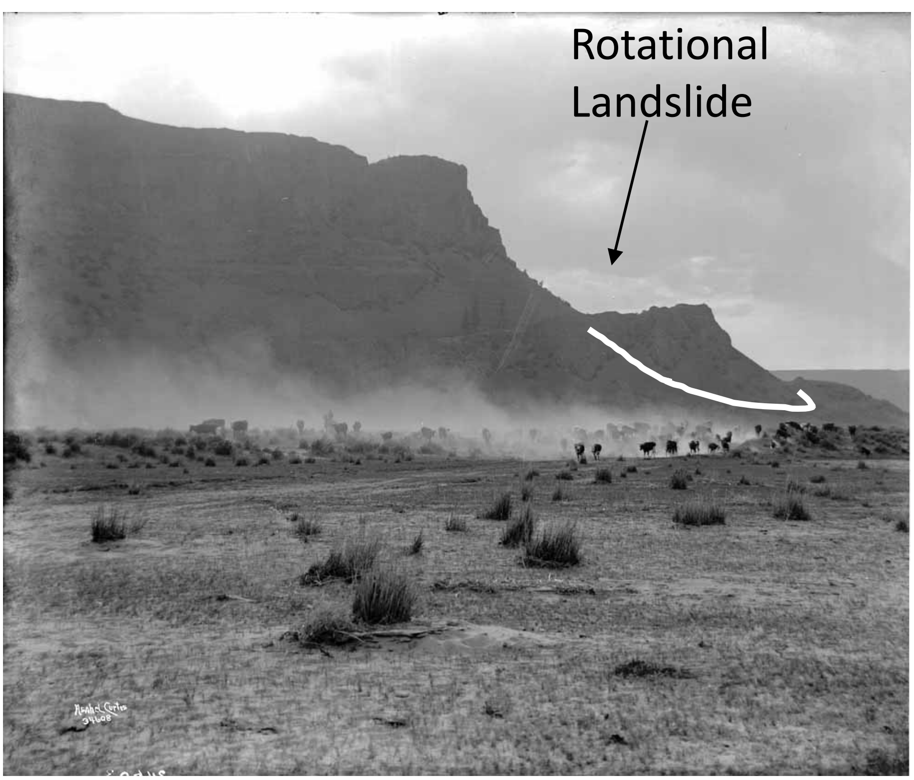


Figure 1-23. Rotational landslide on north end of Steamboat Rock. Curved arrow show presumed slide motion. In the foreground, a cowboy herds cattle on the floor of the Upper Grand Coulee, an area now under Banks Lake. Source: Ashahel Curtis photographer, May 1916, Curtis 34608, Album 32, p. 192, Washington State Historical Museum.

Stop 1-4: North End of Steamboat Rock

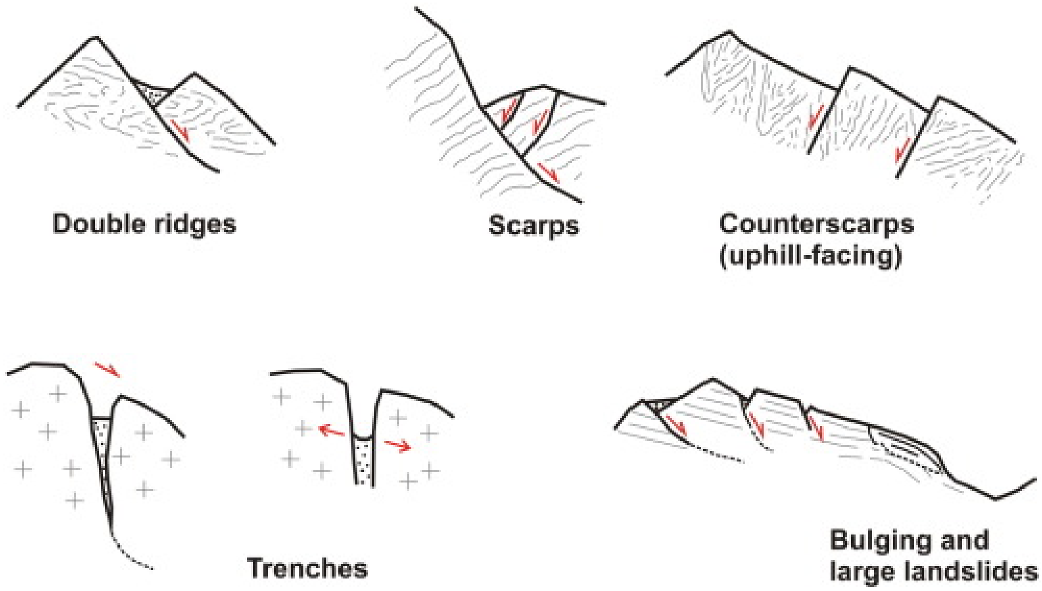


Figure 1-24. Main forms of sacking. Source: Panek and others, 2015.

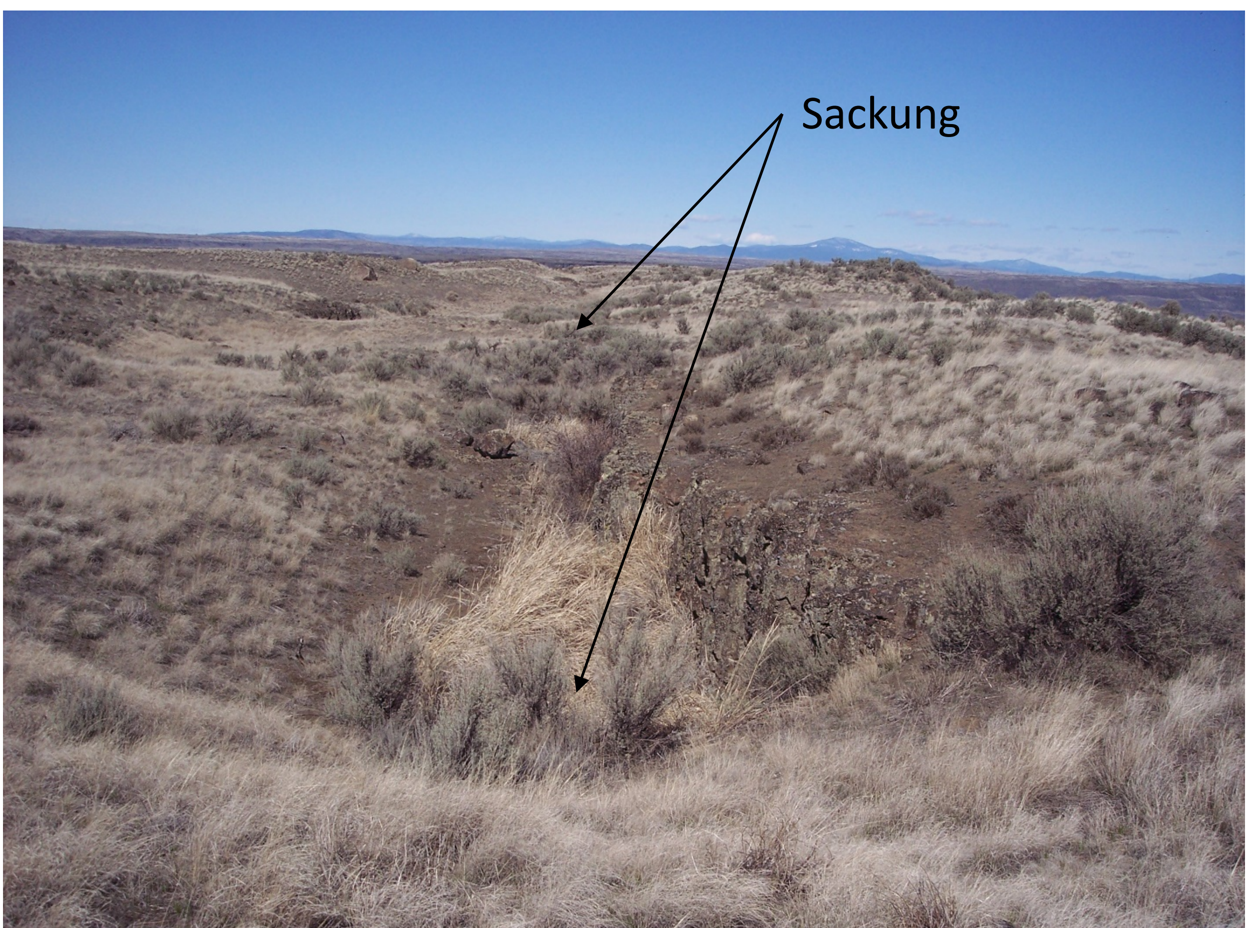


Figure 1-25. Sackung on north end of Steamboat Rock. Source: Karl Lillquist, March 2014.

Stop 1-4: North End of Steamboat Rock

What are the curved lines evident here on Google Earth? Curvilinear features are visible in the basalts on the north end of Steamboat Rock (Figure 1-21). These occur in the Priest Rapids Member of the Wanapum Basalts. The orientation transverse to flood flows suggests they are basalt flow features rather than flood-created features (Bjornstad and Kiver, 2012). Might they be the remnants of *ring dike structures* like those found in the Odessa area south of here? Ring dike structures have been attributed to rising lava encountering wet conditions. Similar features have previously been identified in the east wall of the Upper Grand Coulee just south of here(Keszthelyi and others, 2009).

Were lakes present in the Upper Grand Coulee after Glacial Lake Columbia? According to Freeman (1937, p. 11 the Upper Grand Coulee contains "a few permanent lakes and many shallow ephemeral lakes that disappear in summer leaving alkali flats". Examination of the 1949 Grant County airphotos reveals that approximately 10 lakes occupied the Upper Grand Coulee in historic times. I say "approximately" because wet years and seasons would have resulted in more lakes and dry years and seasons, fewer. They were likely fed by seasonal runoff from snowmelt and rainfall as well as groundwater. Most must have been closed basin lakes and historic airphotos suggest most were shallow and saline. As a result of their salinity and ephemeral nature, the coulee bottom adjacent to most of these lakes appeared to be little developed for agriculture. Devils Lake in the vicinity of Steamboat Rock was an exception (Figures 1-26 & 1-27). It was fed by perennial flow from Northrup Creek and was supposedly sufficiently fresh to be used for irrigation in the bottom of the coulee.

How did humans use this landscape prior to Banks Lake? Native Americans used the area at least seasonally for root gathering, and for hunting various wildlife including waterfowl and their eggs on lakes such as Devils Lake. However, the available literature record of this occupation is scant. Euroamerican homesteaders began moving into the area in the late 1800's. While there may have been irrigated farming near Devils Lake, most of the farms appear to have been of the *dryland* (or *rainfed*) variety. You can see the farms surrounding the Steamboat Rock area as of 1949 on Figures 1-14, 1-19, and 1-27.). Poor accessibility and shallow soils prevented farming from occurring on Steamboat Rock; however, local ranchers such as William "Steamboat Bill" Andrews reportedly herded their horses up here in the spring for the lush grasses (Evans, 1976a). Given the surrounding farms, sufficient residents lived in the vicinity to support a school. Upon starting in about 1900, Steamboat Rock School was the first rural school in the Upper Grand Coulee. Over time, it occupied several locations depending on where the families with children resided. From ~1908 to 1934, it was located "midway on the north side of the rock" (Figures 1-27 and 1-28) (Evans, 1976, p. 35-36).

What's the origin of Banks Lake? Banks Lake is a reservoir in the Upper Grand Coulee impounded by the North Dam at Grand Coulee and the South Dam at Coulee City. Water is pumped up from the Columbia River (impounded as Lake Roosevelt) to fill this reservoir. 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 focused on the Quincy Basin, Royal Slope, and Pasco Basin. Banks Lake began to form in late Spring 1951 (Simonds, 1998). By then, the scattered farms and small communities had been removed from the lake floor.

Stop 1-4: North End of Steamboat Rock

Figure 1-26. Postcard view of northwest side of Steamboat Rock. Note Devils Lake and waterfowl in foreground. Source: https://www.hippostcard.com/listing/mid-1900s-steamboat-rock-upper-grand-coulee-wa-postcard/16527479

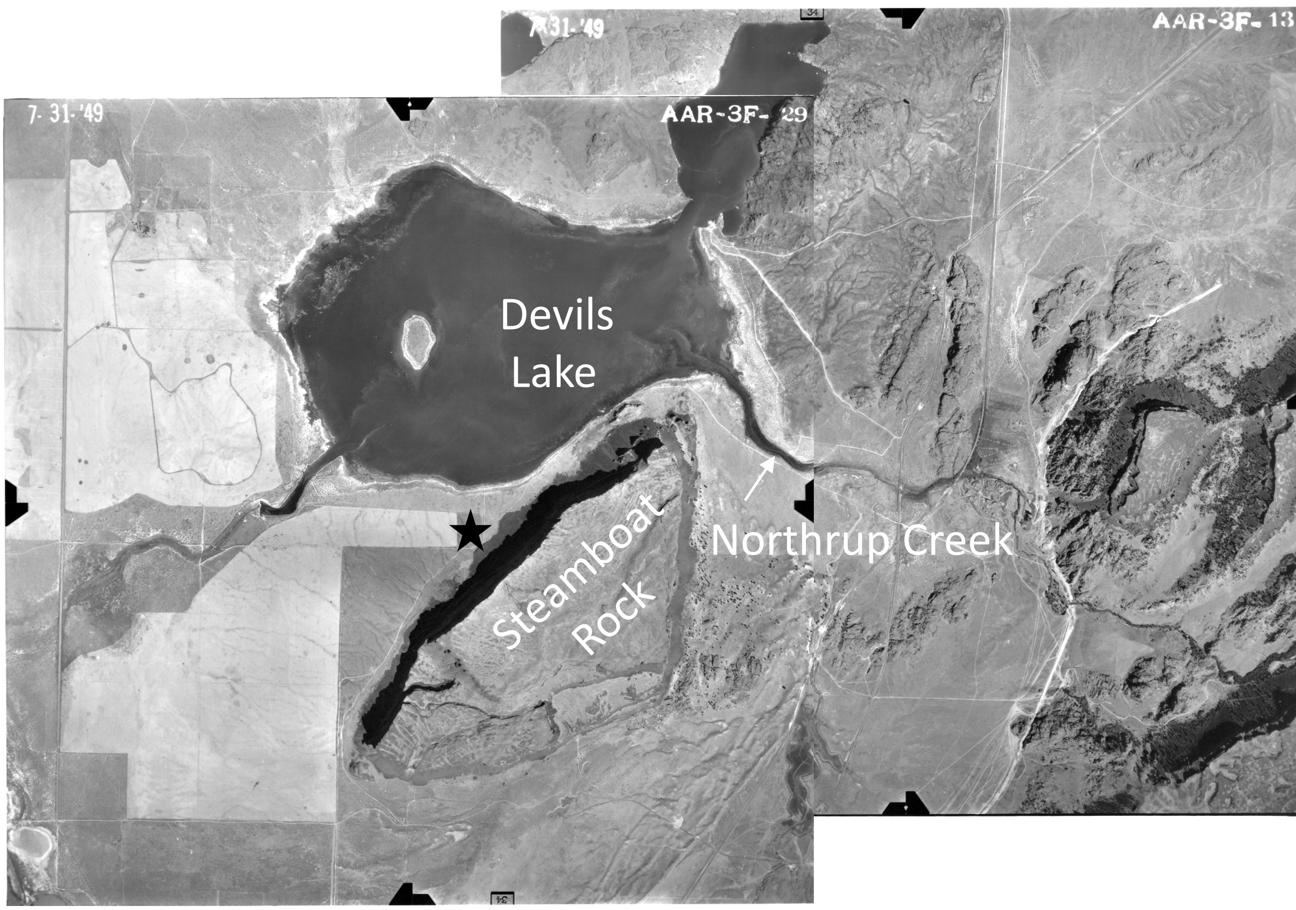


Figure 1-27. Vertical aerial view of Devils Lake and Northrup Creek in relationship to Steamboat Rock in the Upper Grand Coulee. Note farmland immediately west and south of Devils Lake. Black star south of Devils Lake is the location of the Steamboat Rock School between 1908 and 1932. Source: USDA –Production and Marketing Administration, Grant County, July 1949 in the Central Washington Historical Aerial Photograph Project.

Stop 1-4: North End of Steamboat Rock

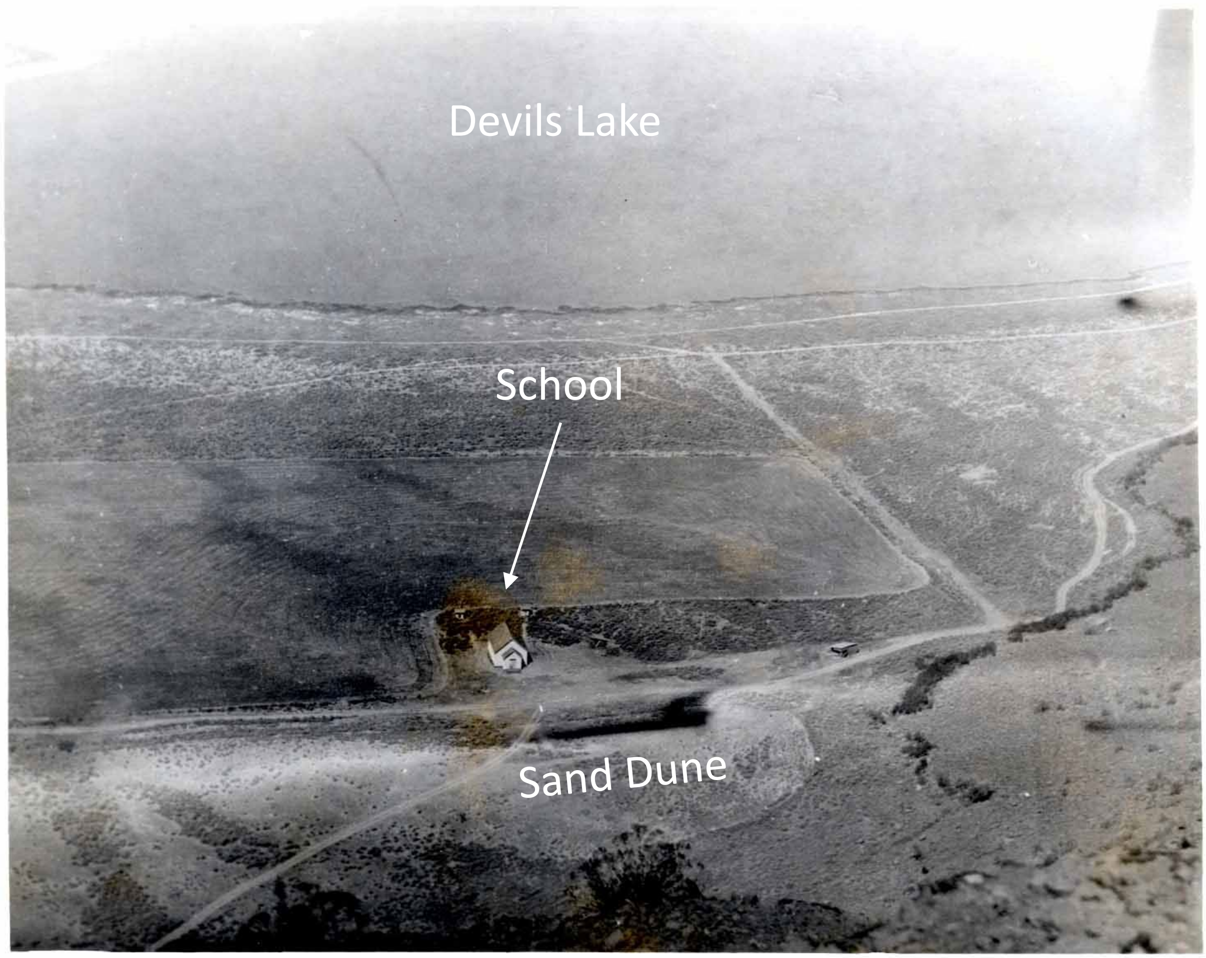


Figure 1-28. Oblique view from top of Steamboat Rock north toward Steamboat Rock School on the west side of the monolith. Back of the photo says 1926-27. It appears that a sand dune is located just south of the school. Source: Unknown photographer, Record group: Educational Service District 171; Subgroup: Grand County Schools; Record Series: Scrapbooks; Dates: 1935-1973; Washington State Central Regional Archives.

Where to next? From here, we will follow a trail south for about 0.4 miles along the east edge of Steamboat Rock to our final stop.

Stop 1-5: East Side of Steamboat Rock

Where are we? We are located on a high spot on the east edge of Steamboat Rock (Figure 1-2) (47.872866°, 119.123465°W).

Is that an unconformity? Looking east from here, we can see rounded, light colored, granitic bedrock overlain by more angular, dark colored basalts. The distinct break between these rock types is an unconformity (Figure 1-29).

What is this ridge? As noted earlier, several moraines are present atop Steamboat Rock. This is one of those moraines. What is unique about this stop is that we can see the interior of the moraine (Figure 1-30). Note the unsorted sediments that have a fine textured matrix and interspersed pebbles, cobbles, and boulders comprising this feature. This is classic glacial *till*. The low degree of weathering of stones in the till suggests that the moraines date from the last glaciation (Crosby and Carson, 1999). Further, the little altered morphology of the moraines suggests that they were deposited after the last of the floodwaters overtopped Steamboat Rock (Crosby and Carson, 1999; Bjornstad and Kiver, 2012).

What is the chronology of development of the Steamboat Rock area? As we come to end of our field day atop Steamboat Rock, it seems appropriate to summarize the sequence of events that have shaped this landscape. Here we go:

Mesozoic and early Cenozoic (~252-~34 million years ago)

- *Granitics emplaced*

Early Cenozoic to mid-Miocene (~34- ~16.5 million years ago)

- Granitics weathered and eroded

Miocene (~16.5-~15.5 million years ago)

- Columbia River Basalts cover area

Late Pleistocene (~20,000-~15,000 year ago)

- Large floods scour area including top of Steamboat Rock
- Floods headwardly erode through divide into Columbia River Valley
- Okanogan Lobe covers area including top of Steamboat Rock
- Smaller floods cover coulee floor
- Glacial Lake Columbia covers coulee floor

Latest Pleistocene & Holocene (~15,000-present)

- Dunes cover parts of coulee floor
- Rockfall, landslides & sackungen occur on Steamboat Rock
- Native Americans travel through and perhaps permanently occupy coulee
- Homesteaders enter coulee
- Banks Lake floods coulee floor

Where's Northrup Canyon? From this viewpoint, we get a view of the mouth of Northrup Canyon, the site of tomorrow's field trip. Note the large flood bar at the mouth.

Where from here? From here, we will follow a trail south into the transverse channel and back down off the rock. Total distance back to the parking lot is about 1.5 miles.

Stop 1-5: East Side of Steamboat Rock

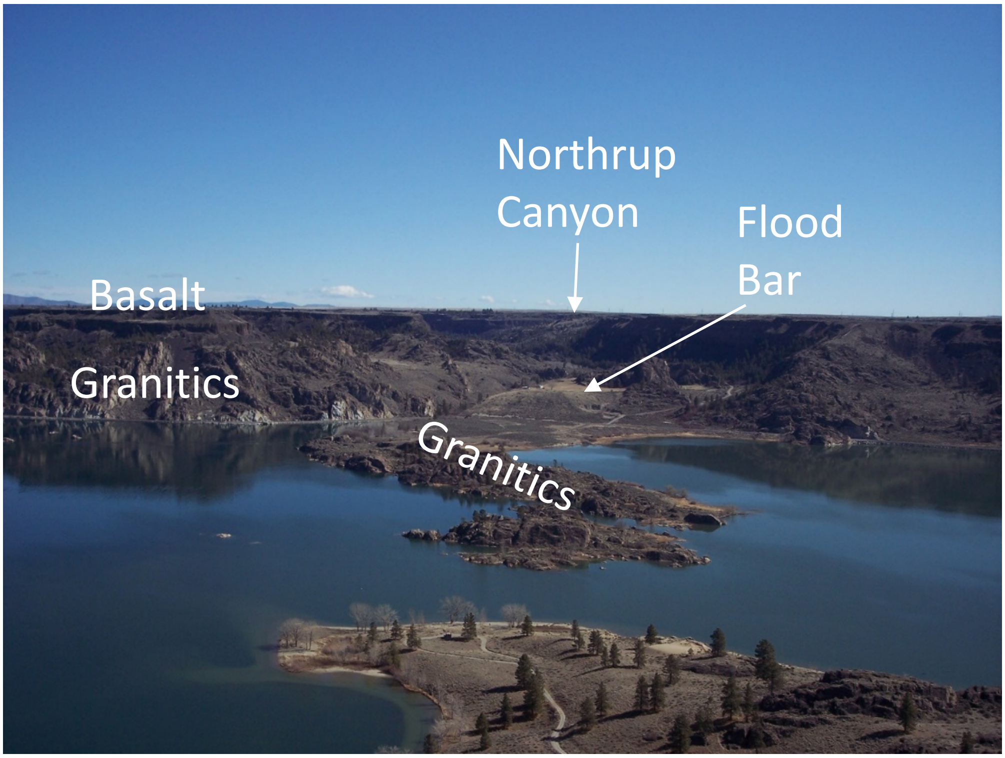


Figure 1-29. View of Northrup Canyon mouth. Note the unconformity between the Columbia River Basalts and the underlying granitic rocks.

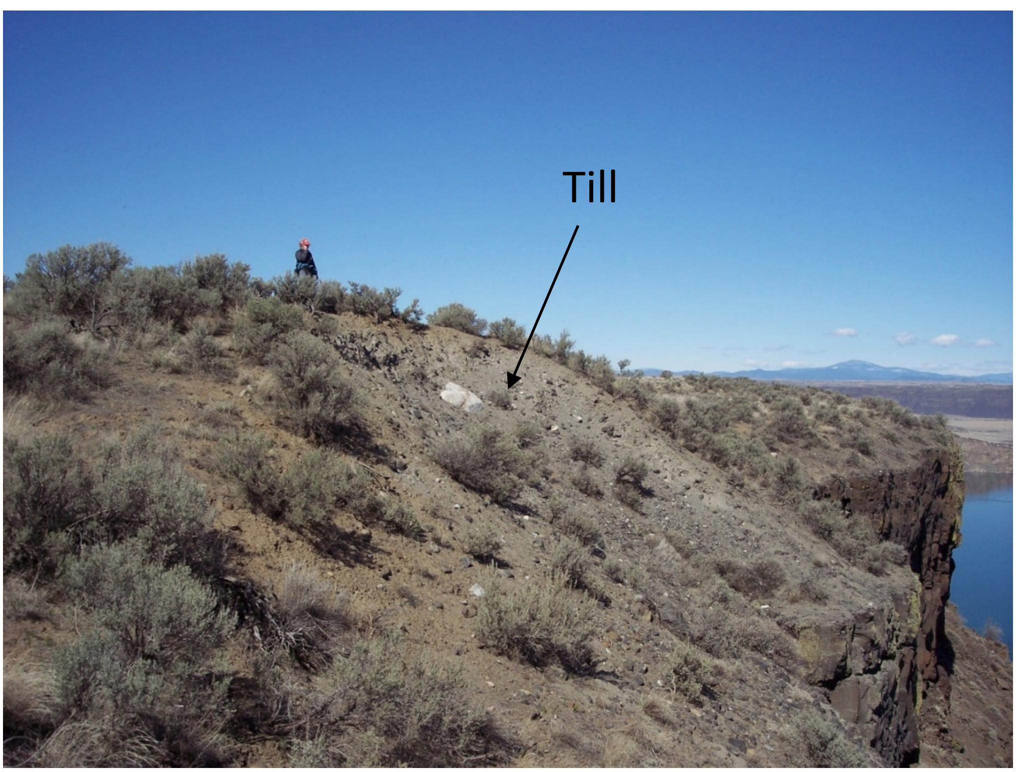


Figure 1-30. Till exposure in end moraine, east side Steamboat Rock. Nancy for scale. Source: Karl Lillquist, March 2014.

Day 2—Northrup Canyon

Sunday 28 April 2019

Field Trip Overview

We will meet at the Northrup Canyon trailhead at 10am. This is about 1 mile east of WA 155 and is reached via Northrup Road. Park in the small parking lot at the trailhead or along the gravel road leading to the trailhead. You will need a Discover Pass to park there. After getting ourselves oriented to the canyon, we will hike on the old road that follows the canyon floor to the original Northrup homestead. Along the way, we will stop to examine bedrock geology (including jointed and exfoliated granites), Ice Age flood evidence, rockfalls and talus, Northrup Creek, Grant County's only forest, and human land use history. The granitic rocks and their response to Ice Age flooding are especially dramatic here. From the homestead, we will return part way down the valley, then veer off over a large flood bar to another homestead and up the old connector road to the Scheibner Grade on the south wall of the canyon. We should have great views of not only Northrup Canyon but also Steamboat Rock and the Upper Grand Coulee from there. From this point, we will continue down the Scheibner Grade back to the parking lot. We should be back by 4 or 5 pm. Total hiking distance is about 4 miles. I would rate this as an easy to moderate hike with the homestead road gentle and the connection to the Scheibner Grade being moderate over uneven rock. Like the Steamboat Rock hike, you are welcome to explore Northrup Canyon with us for all or part of the day.

Tentative Schedule

10:00am	**Stop 2-1—Northrup Canyon Trailhead**
10:45	**Depart**
11:15	**Stop 2-2—Mid-Canyon Flood Bar**
11:45	**Depart**
12:15pm	**Stop 2-3—Northrup Homestead (discussion + lunch)**
1:30	**Depart**
2:00	**Stop 2-4--Northrup Creek Bridge**
2:30	**Depart**
3:00	**Stop 2-5—Scheibner Homestead**
3:30	**Depart**
3:45	**Stop 2-6—Scheibner Grade**
4:00	**Depart**
4:30	**Arrive at Northrup Canyon Trailhead**

Stop 2-1: Northrup Canyon Trailhead

Where are we? We are located about 100 yards northeast of the Northrup Canyon Trail parking lot at a canyon viewpoint (Figure 2-1) (47.866905°N, 119.081998°W).

What's that white/gray rock? Northrup Canyon lies at the boundary of the Miocene Columbia River Basalts and the underlying Mesozoic granitic rocks. The basalts are dark, dense, fine-textured extrusive igneous rocks while the granitics are lighter colored, coarse-textured intrusive igneous rocks. The unconformable contact separating the basalt from the underlying granitics can be seen in the coulee walls to the north of here. Such a boundary between different rocks may also be thought of as a *geotone*. The geology dictates the landforms, soils, water, and vegetation patterns here—i.e., the character of Northrup Canyon differs greatly depending on which geology one is in. We will talk about this more in the coming stops.

Why do trees grow here? Northrup Canyon also lies at a climatically-induced *ecotone* where vegetation of the shrub steppe intermingles with Eastside forest. Indeed, this is really the only "forest" in all of Grant County! Moisture is the key factor shaping vegetation patterns here. The climate is considered to be semi-arid and continental (i.e., hot summers and cold winters). Coulee Dam (~8 miles north) receives an average of just under 11 inches/year (Figure 1.3). Sagebrush- and bunchgrass-dominated shrub-steppe vegetation is the primary vegetation on the plateau above as well as on the drier south-facing slopes in the canyon. On north-facing slopes, sufficient moisture is present to support the Douglas fir and ponderosa pine characteristic of Eastside forest. The moist canyon floor includes elements of the Eastside forest plus quaking aspen, red osier dogwood, and other water-loving species.

Was Northrup Canyon shaped by Ice Age flooding? Northrup Canyon consists of four former channels that were formed by Ice Age floodwaters. They resulted from headward recession in the basalts, and to a lesser degree, in the granitics. A wetland and a wetland pond occupy the heads of the two westernmost channels. Northrup Lake occupies the plunge pool at the head of the northeastern channel. How do we know that Northrup Canyon resulted from Ice Age floods rather than forming slowly over thousands of years? First, the canyons are *coulees*—i.e., steep-sided and relatively flat floored. Such forms are found wherever Ice Age floods interacted with basalt. All four channels of the overall canyon generally trend north-south, the same direction that Ice Age floods would have entered the area. The three westernmost channels end near where the Upper Grand Coulee truncates the basalt plateau above us suggesting that these served as flood channels <u>prior to</u> the excavation of the Upper Grand Coulee. Finally, several large bars are present in the canyon. Elsewhere, such features have been attributed to huge floods. We will talk more about these bars at the next stop.

How old is Northrup Canyon? Dr. Andrea Balbas, then a Geology PhD student at Oregon State University, sampled and dated three sites in lower Northrup Canyon. Her cosmogenic ^{10}Be dating reveals that the granite bedrock here was exposed by Ice Age floods about 15,600 years ago (Balbas and others, 2017). Given that Northrup Canyon and the Upper Grand Coulee meet at essentially the same elevation (and that Northrup Canyon is not a *hanging valley* above the Upper Grand Coulee it makes sense that the Grand Coulee had receded to the mouth of Northrup Canyon by about 15,600 years before present. However, the breach of the western channel and the near breaches of the adjacent two channels indicates that the Upper Grand Coulee had not yet receded to those points when Northrup Canyon was eroded. Further, this means that the Upper Grand Coulee had not receded to, and opened its low elevation connection with, Glacial Lake Columbia until after ~15,600 years before present. A cosmogenic ^{36}Cl date on a granite inselberg near Electric City suggests this occurred around 17,200 years before present (Baker and others, 2016). While the numbers are not perfect, they do suggest all of this happened in the late Pleistocene.

Stop 2-1: Northrup Canyon Trailhead

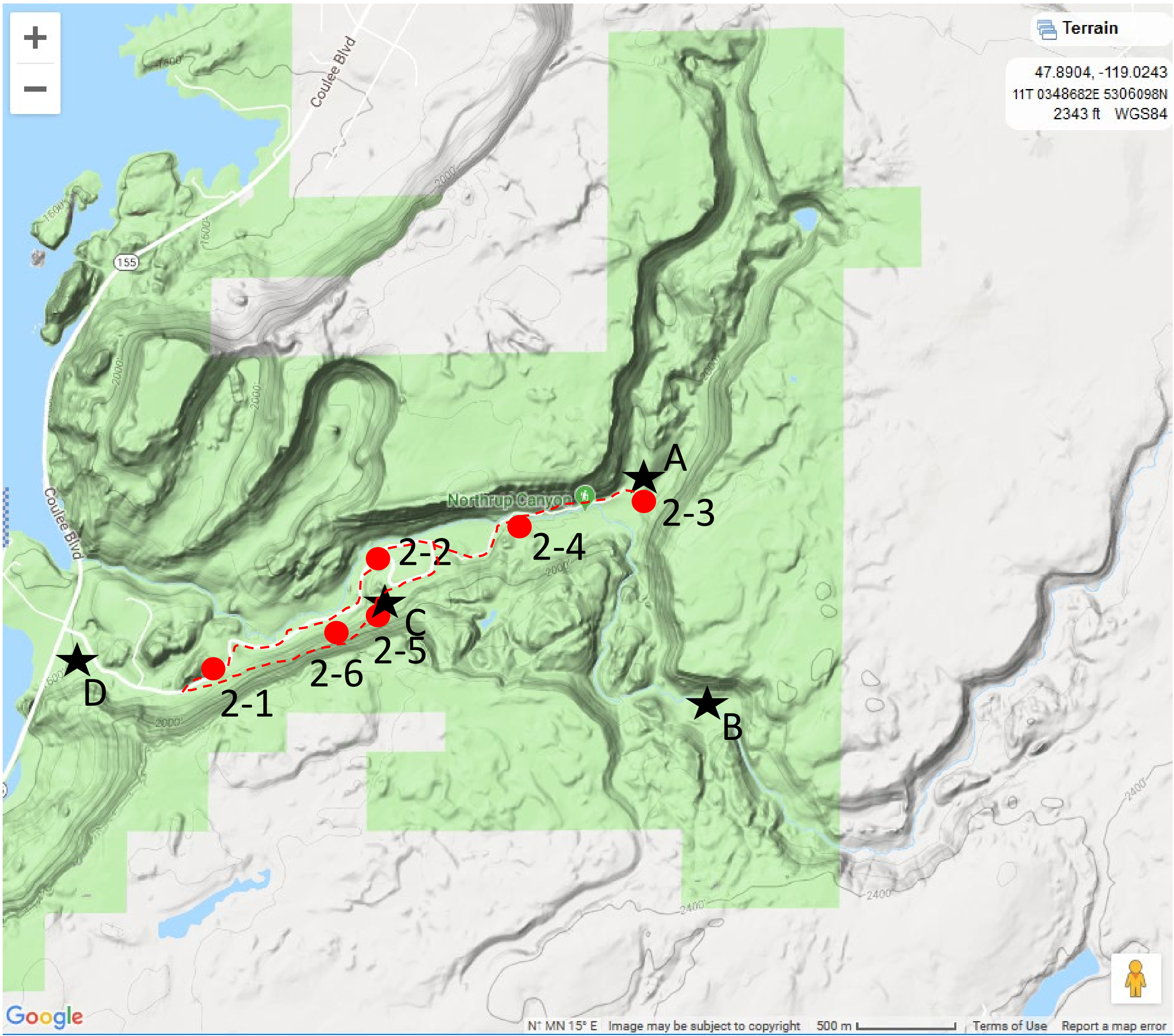


Figure 2-1. Northrup Canyon and its four sub-canyons. Numbers and red dots indicate approximate locations of field trip stops. Letters and black stars indicate late 19th and early 20th century homesteads including: A = Northrup; B = Sanford; C = Scheibner; D = Dillman. Green area is Steamboat Rock State Park. Source: Google Maps; .

Stop 2-1: Northrup Canyon Trailhead

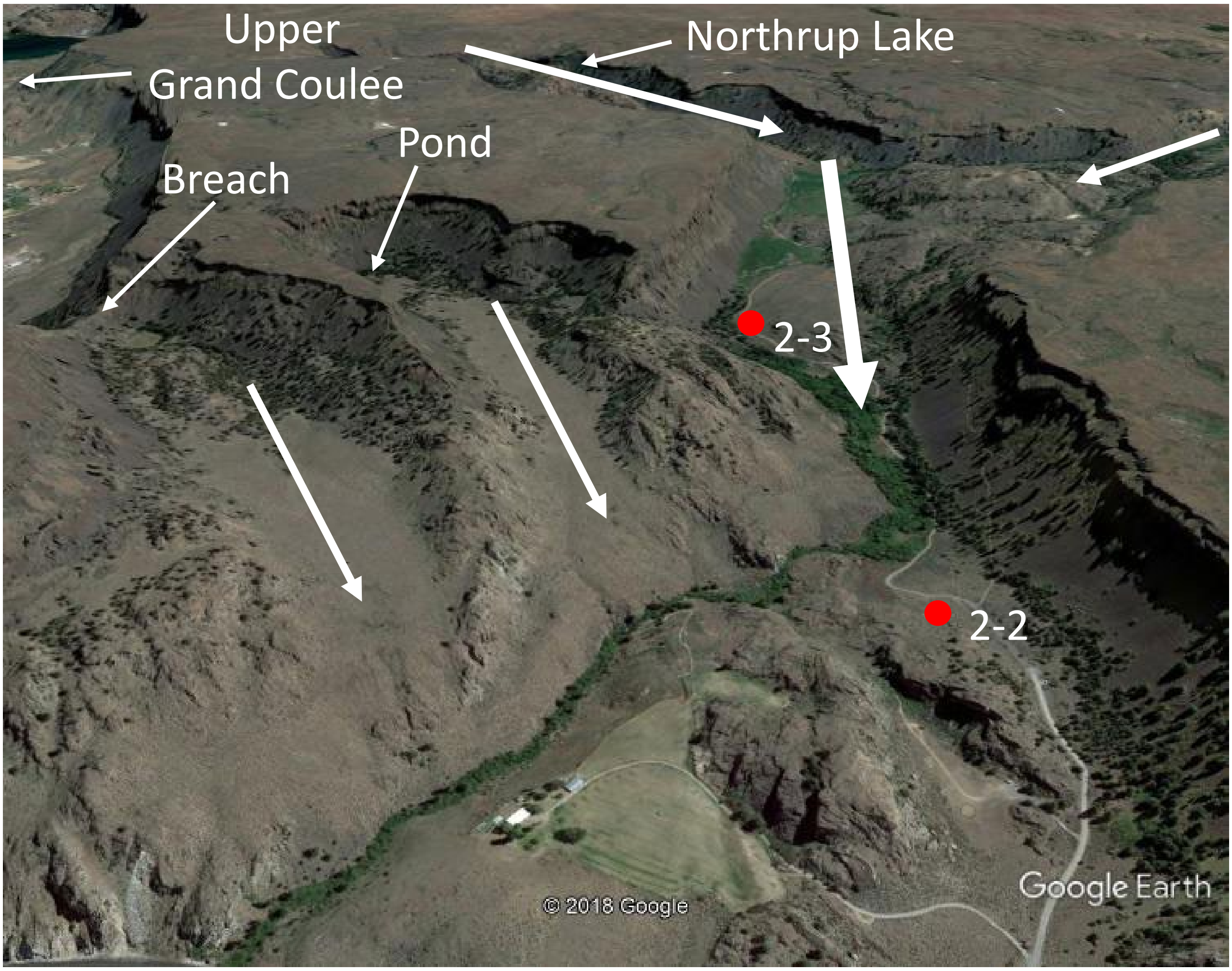


Figure 2-2. Oblique aerial view of three of the branches of Northrup Canyon. View east northeast. Note how the head of the westernmost branch was truncated by the Upper Grand Coulee. Source: Google Earth.

How have humans interacted with Northrup Canyon? Canyons are often places humans frequent. They may offer protection from the elements, especially wind and sun. Water is often present in canyons when it is rare in surrounding drylands. That is the case here. Canyons offer topographic diversity which, when combined with the ecotonal nature of this place, means much biological diversity. Biological diversity has long attracted humans. While little has been written about Native Americans in Northrup Canyon, it seems plausible that they exploited a variety of resources in and around the canyon including various root crops, small and large mammals (including black bears and bison), birds, fish, and reptiles (Larrison, 1943, 1944; Johnson and others, 1950; Anglin, 1995). It was the protection from the elements, water, and the biological diversity (especially trees) that brought homesteaders here in the late 1880's. Canyons are often the pathways from one place to another. Northrup Canyon has long been a way to safely and efficiently move from the Upper Grand Coulee to the plateau above and to the east.

Where to next? From Stop 2-1, we will follow the road up the bottom of the canyon for approximately 0.7 miles to the western edge of a large flood bar.

Stop 2-2: Mid-Canyon Flood Bar

Where are we? We are located near the west end of the large Ice Age flood bar in mid-canyon (Figure 2-1) (47.871555°N, 119.071318°W).

What is this large, sagebrush-covered surface? At Stop 2-1, I noted that giant bar deposits are evidence of huge floods, and that huge Ice Age floods occurred here. Flood bars on "normal" (i.e., non-flooding rivers) are typically tens of feet long. The bar here is a relatively small Ice Age flood bar and it is ~1,340 feet long by ~670 feet wide by 60 feet high (Figure 2-3)! Here's what indicates to me that this is a flood bar rather than some other valley bottom feature: 1) flood bars are typically composed of coarse sediments—i.e., sands and gravels—that reflect their high energy origins; 2) large boulders often pepper the surface of bars; 3) their transverse profiles are normally convex upward; 4) because of the coarse nature of the sediments, bars are often not farmed nor do they support dense natural vegetation; 5) bars may have different levels that look like terraces; and 5) bars ordinarily have a low spot known as a *fosse* where they abut bedrock. This bar has most of these characteristics. The big sagebrush growing here is not the norm for an Ice Age flood bar; however, it could

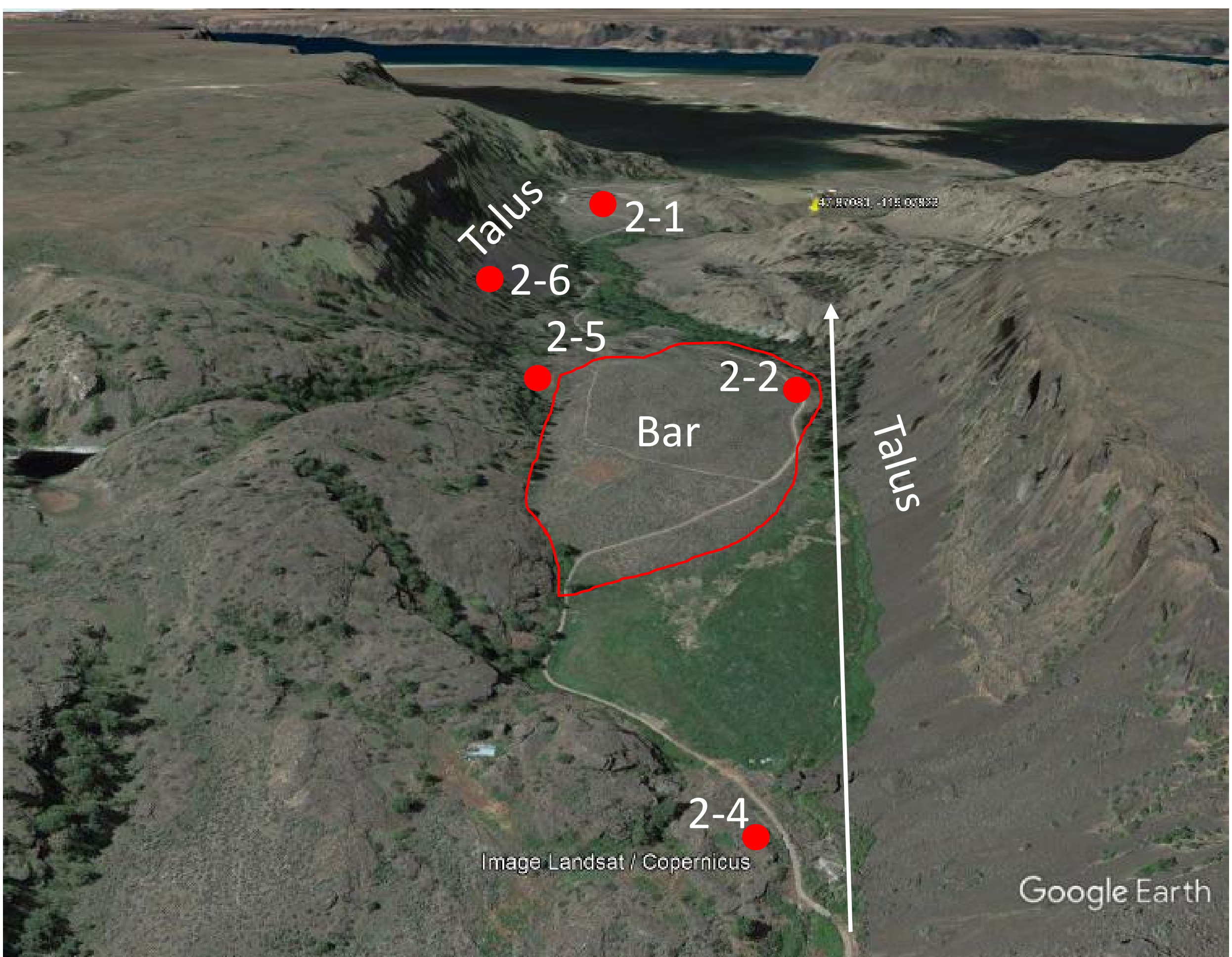


Figure 2-3. Oblique aerial view of mid-canyon Ice Age flood bar, Northrup Canyon. View downstream toward the west. Note the talus associated with the steep basalt cliffs. Approximate locations of field trip stops shown with red dots and numbers. Source: Google Earth.

Stop 2-2—Mid-Canyon Flood Bar

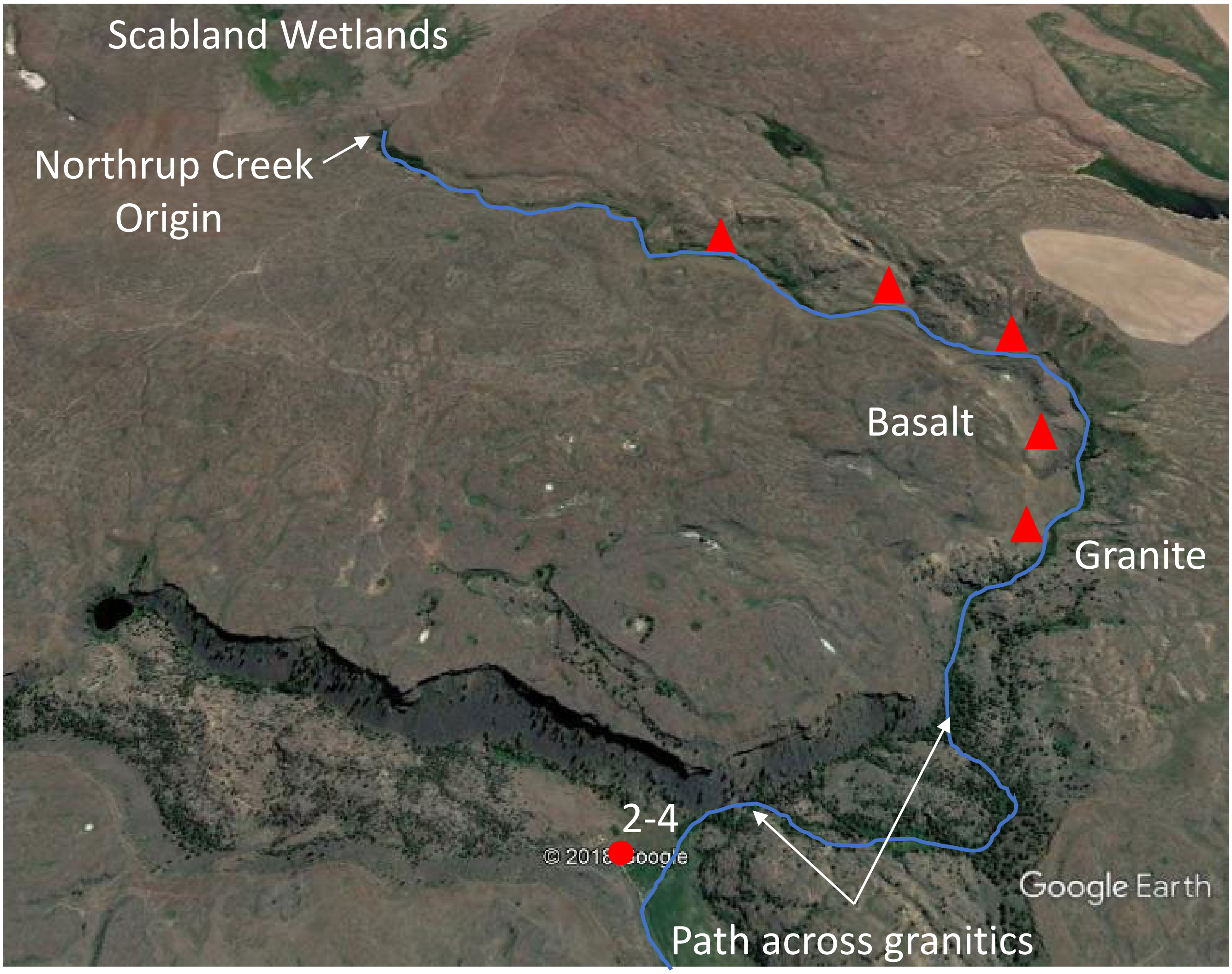


Figure 2-4. Oblique aerial view of eastern arm of Northrup Canyon. View east-northeast. Note origins of creek in springs below scabland wetlands. Red triangles indicate ice age flood bars in the canyon. Also, note route of creek (blue line) at the granitic-basalt boundary in the upper reaches, and across the granitics in the lower reaches. Source: Google Earth.

What is the large, sagebrush-covered surface? (continued)…suggest that the bar is capped with windblown, fine textured *loess*. Bjornstad and Kiver (2012) call this a *pendant/crescent bar*. It formed on the south side of the canyon as the main floodwater flowed immediately north. It also formed in the lee of the granite bedrock on its upstream end and partially buried the bedrock on its downstream end. Another five Ice Age flood bars are present in the easternmost branch of Northrup Canyon (Figure 2-4).

What's the origin of the large boulders at the base of the cliff? The north canyon wall here is over 400 feet tall. When eroded by Ice Age floods, we can assume that it was essentially vertical. And given the location of the giant flood bar, it appears that floodwaters undercut the basalt cliff enhancing its verticality. Following the flooding, rockfall formed a prominent apron of talus along this slope. The smaller rocks of the talus likely represent the effects of frost action and gravity on the columnar joints and the entabulature so typical of Columbia River Basalt flows (Figure 1-6).

Stop 2-2: Mid-Canyon Flood Bar

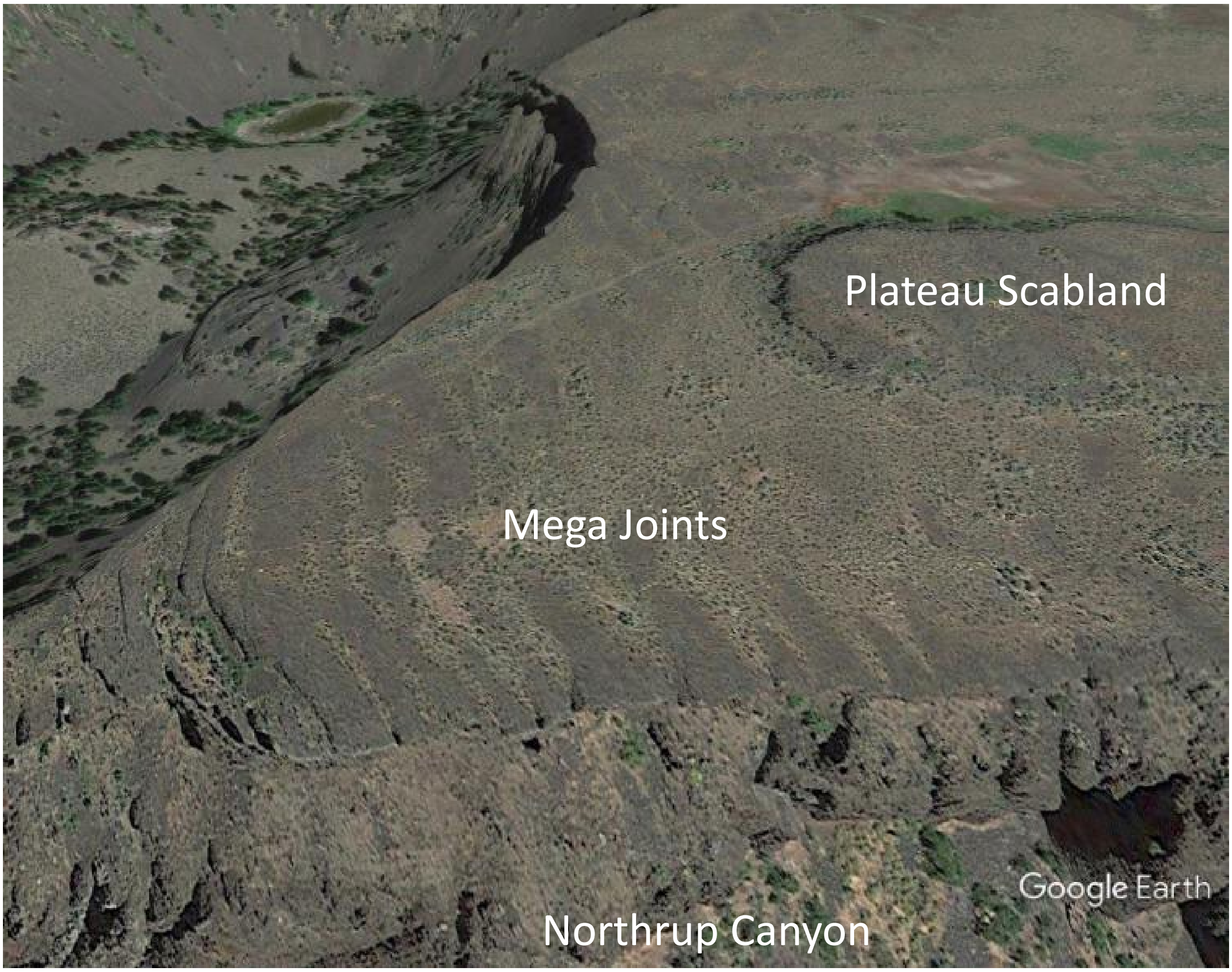


Figure 2-5. Oblique aerial view of plateau scabland immediately north of Northrup Canyon. Note the parallel joint pattern running approximately NW to SE. View to the north. Source: Google Earth.

What's the origin of the large boulders at the base of the cliff? *(continued)…*The larger boulders, some of which are up to 15 feet in diameter, at the base of the slope are likely also a product of rockfall but from a larger joint pattern evident from above (Figure 2-5). I'm not clear how or when this jointing pattern formed—i.e., was it during cooling or did it occur later with regional tectonic stresses—but it is a common feature of the basalts including those of Steamboat Rock (Figure 1-17). It is also possible that some of the large boulders in the vicinity were flood-transported but given their proximity to the coulee wall, it is likely most resulted from rockfall.

Where to next? From here, we will continue up the canyon for about 1 mile to the Northrup Homestead. In dry conditions, we can follow the valley floor road. However, during high runoff, we will need to walk on the old, partially overgrown and talus-covered road higher on the slope.

Stop 2-3: Northrup Homestead

Where are we? We are located at the Northrup homestead at the east end of the main arm of Northrup Canyon. Northrup Canyon was a crossroads and an oasis in the desert (Figure 2-1) (47.874163°N, 119.053610°W).

How did the granitics interact with Ice Age floods? Upvalley of the large Ice Age flood bar, granitic bedrock becomes much more evident. The granitics responded to Ice Age floods very differently than did the vertically jointed basalts. The vertical, columnar jointing characteristic of basalts allowed them to be plucked much more readily from the surrounding bedrock than the linear jointing of the granites (more on this at Stop 2-4). Plucking is key to initial incision and subsequent headward erosion that characterizes coulee formation in basalts. Because the granitic rocks aren't easily plucked, they remain behind as rounded islands and ridges within the coulees, almost always with a deep moat-like feature at the contact with the basalt (Figure 2-6).

Why and when was the canyon occupied by humans? Water is key to desert settlement. Northrup Creek is one of a handful of perennial streams in the heart of the Columbia Plateau. In addition, springs, seasonal wetlands, and perennial ponds dot the canyon. The shrub steppe-Eastside forest ecotone meant it was a rich place for flora and fauna, and the relative abundance of the water enhanced this. The canyon walls provided protection from cold winds in the winter and the heat of summer. The trees of this Eastside forest attracted settlers who needed them for home, outbuilding, and fence construction. And the soils on parts of the floor of the canyon were fertile and "sub-irrigated" by Northrup Creek. I assume that Native Americans lived in Northrup Canyon, at least seasonally beginning after the passage of the last of the Ice Age floods. However, the archaeological record is not clear on this. We do know that homesteaders came into the canyon beginning in the late 1880's. In fact, there were at least four homestead sites in the canyon (Figure 2-1) in the early years. We are located at the most prominent of the four—the Northrup homestead site.

Who were the Northrups? John W. Northrup purchased land in Northrup Canyon in 1889. Thus began nearly 40 years of Northrups living in the canyon. John and his wife Caty, and later John's son George, his wife Joella and their kids and spouses farmed and raised livestock in the canyon. In 1926, Joella and son Charles were the last of the Northrups to leave the canyon (Washington State Parks, 2010). Drought, water rights issues, and a mortgage apparently drove them out (Thompson, 1976; Joella Northrup Campbell, personal communication, April 2019).

The structures here include the first Northrup house that was constructed in about 1890 (Figures 2-7, 2-8 & 2-9). Logs must have come from the nearby Eastside forest. Rough sawn boards within were milled at the Scheibner sawmill downvalley (Evans, 1976c). Other buildings dating to the Northrups include the smokehouse, root cellar, milk house, and water tank (Figure 2-7). Water was delivered to the house from a spring up the canyon to the north via a flume and ditch (Thompson, 1975).

Over time, the Northrups grew a variety of vegetables including corn, potatoes, squash, cabbage, peas, tomatoes, pumpkins, and many types of berries. The orchard started by John W. Northrup included 29 different varieties of fruit (including apples, peaches, cherries, and apricots) and may have been the first in Grant County. Apples and peaches appear have been the main fruit grown and were known for miles around (Figure 2-10). Other crops included alfalfa, wheat, flax, oats, and barley. They also raised cows, pigs, horses, sheep, chickens, turkeys, and geese. (Evans, 1976c; Northrup, 2003; Washington State Parks, 2010). Fruit and

Stop 2-3: Northrup Homestead

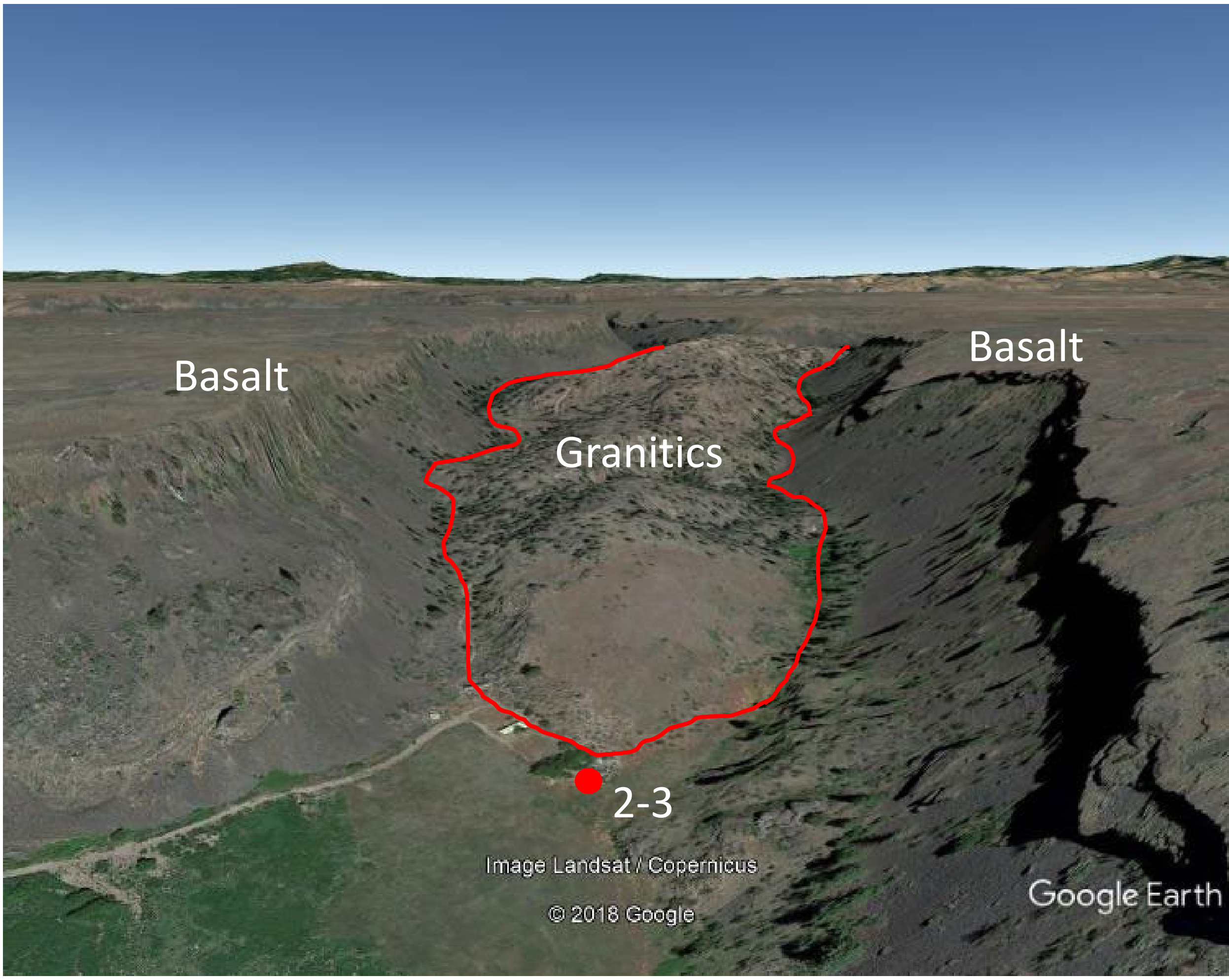


Figure 2-6. Oblique aerial view up Northrup Canyon north of Northrup Homestead. Note the partially eroded granitic ridge in center of canyon with moat-like features at the contact with the adjacent basalt. Northrup Lake lies at the end of the canyon. Source: Google Earth.

Who were the Northrups? (continued)…vegetables grown here were transported by horse and wagon up the Scheibner Grade (Stop 2-6) to farm families in the Hartline and Almira areas south and southeast of here. Farm families also made the trek to Northrup Canyon to purchase fruit and enjoy the oasis nature of the place (Thompson, 1975; Evans, 1976c). Crops here need sufficient growing season temperatures, good soil, and water. The soil has often been described as fertile and may have its origins as an early lake (Bjornstad and Kiver, 2012) impounded behind the bedrock near the Northrup Creek bridge. Additionally, alluvium from Northrup Creek and loess from previous dust storms likely cover the canyon floor.
Who came after the Northrups? The post-Northrup record of human occupation is less clear. Metsker's atlases dated 1933 and 1961 suggest that the and changed hands several times. However, a 1955 airphoto shows that it was actively being farmed (Figure 2-11).
Where to next? From here, we will retrace our steps about 0.5 miles to the bridge over Northrup Creek. Our stop will be atop the granite outcrops above the bridge.

Stop 2-3—Northrup Homestead

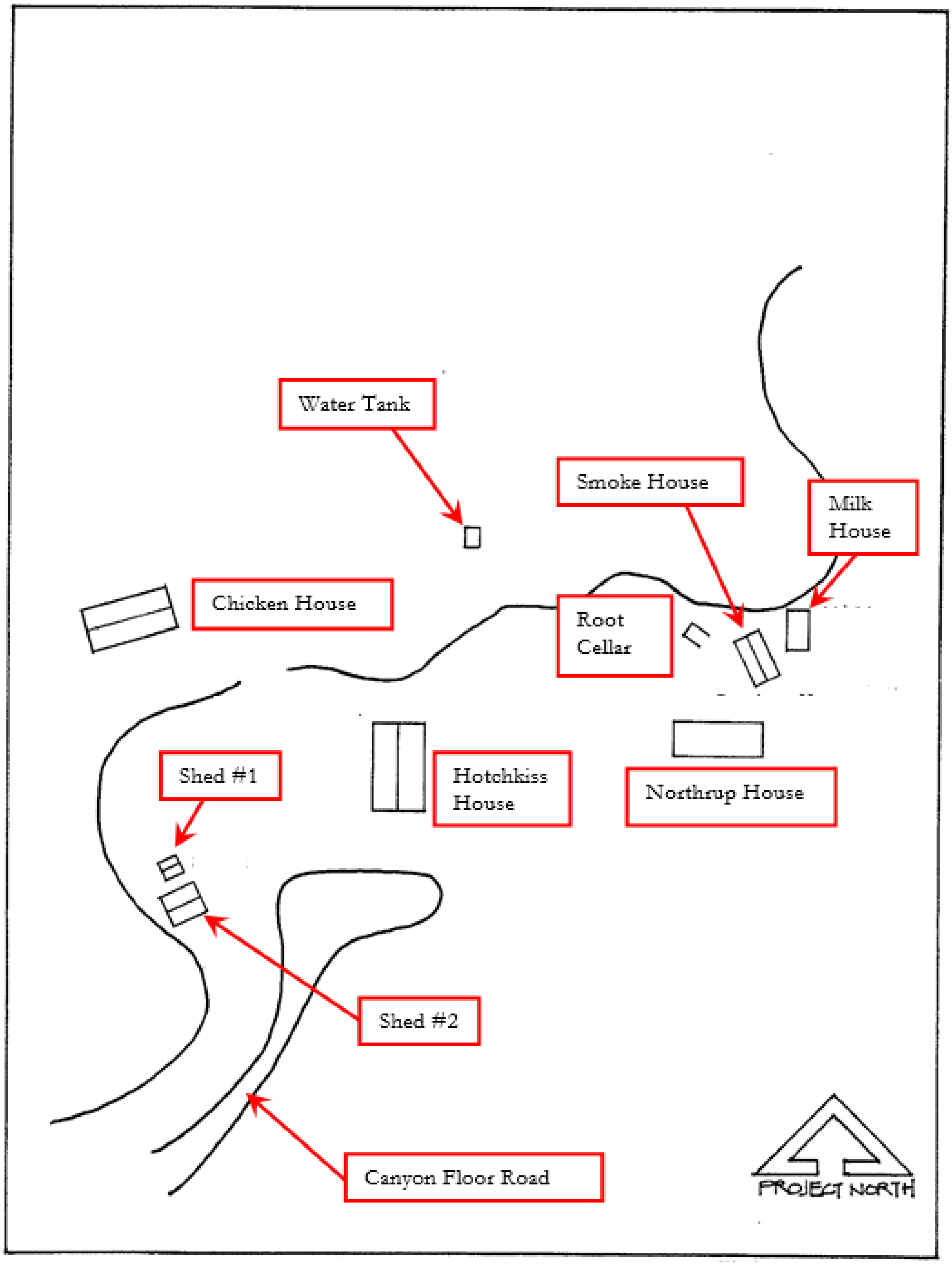


Figure 2-7. Site plan of the Northrup Homestead. The orchard and gardens lay east of the north end of the canyon floor road. Source: Washington State Parks (2010), Appendix 3.

Stop 2-3: Northrup Homestead

Figure 2-8. Original ~1890 Northrup house (left) with ~1892 addition (right). 1903 frame house collapsed on right just out of picture. Since its origins as a home it has been used as a livestock stable. View to north. Source: Karl Lillquist, March 2019.

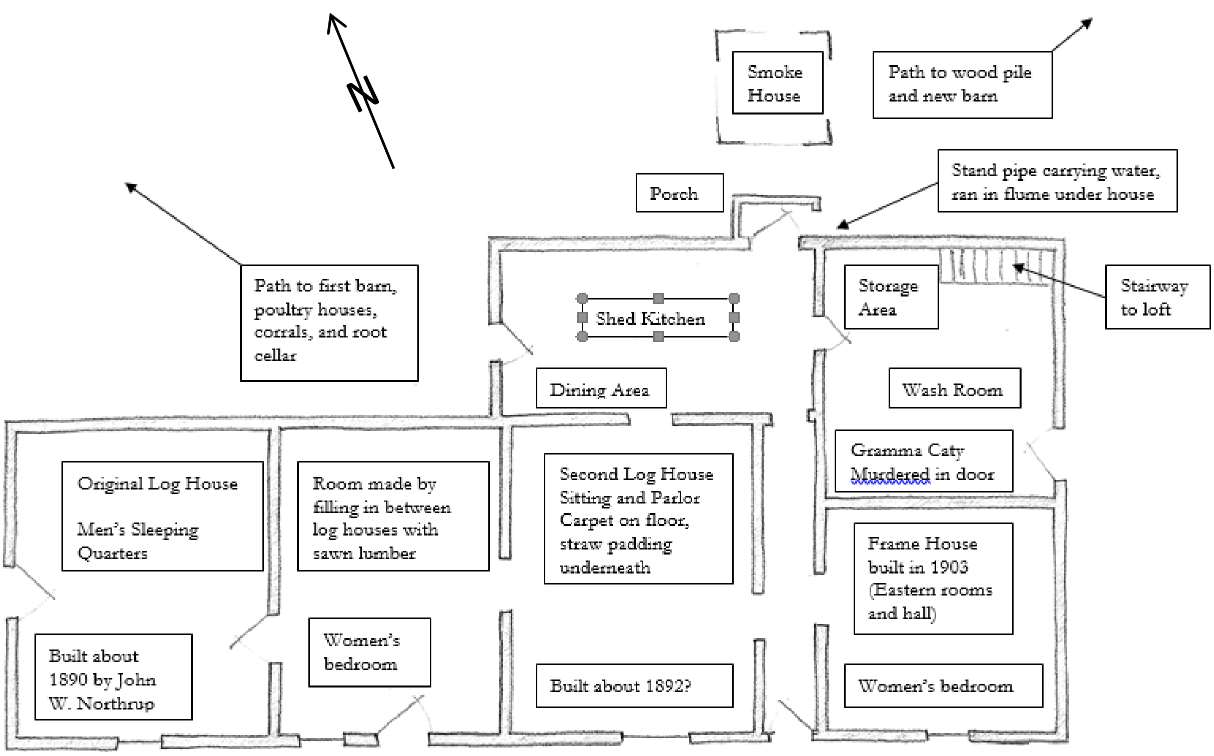


Figure 2-9. Detailed plan of Northrup house. Based on sketch made by Charles Northrup who lived in the house from 1903-1926. Source: Washington State Parks (2010) Appendix C.

Stop 2-3: Northrup Homestead

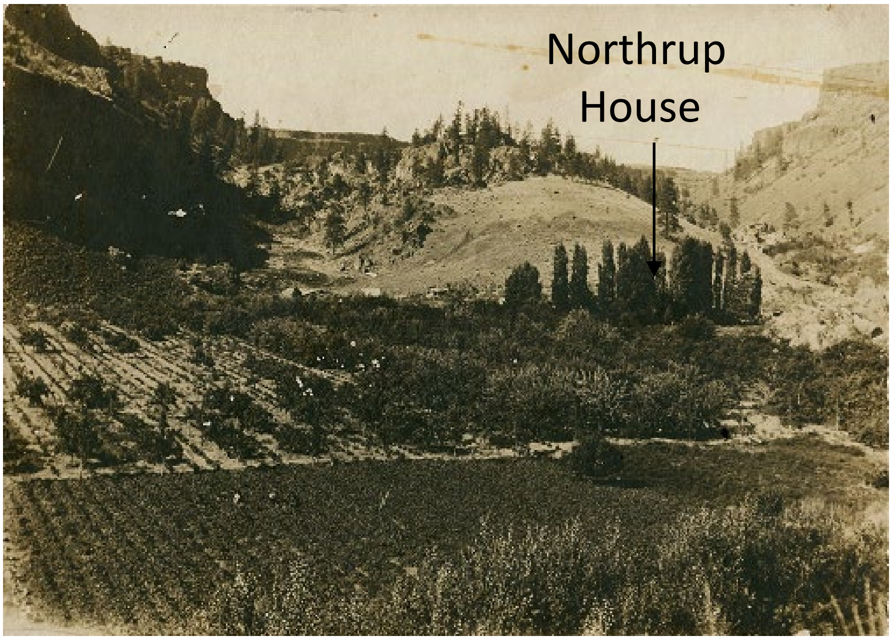


Figure 2-10. Northrup homestead with associated orchard and farm fields. View north up branch toward Northrup Lake. Note Northrup house. Photo taken between 1895-1900. Source: Joelle Northrup Campbell.

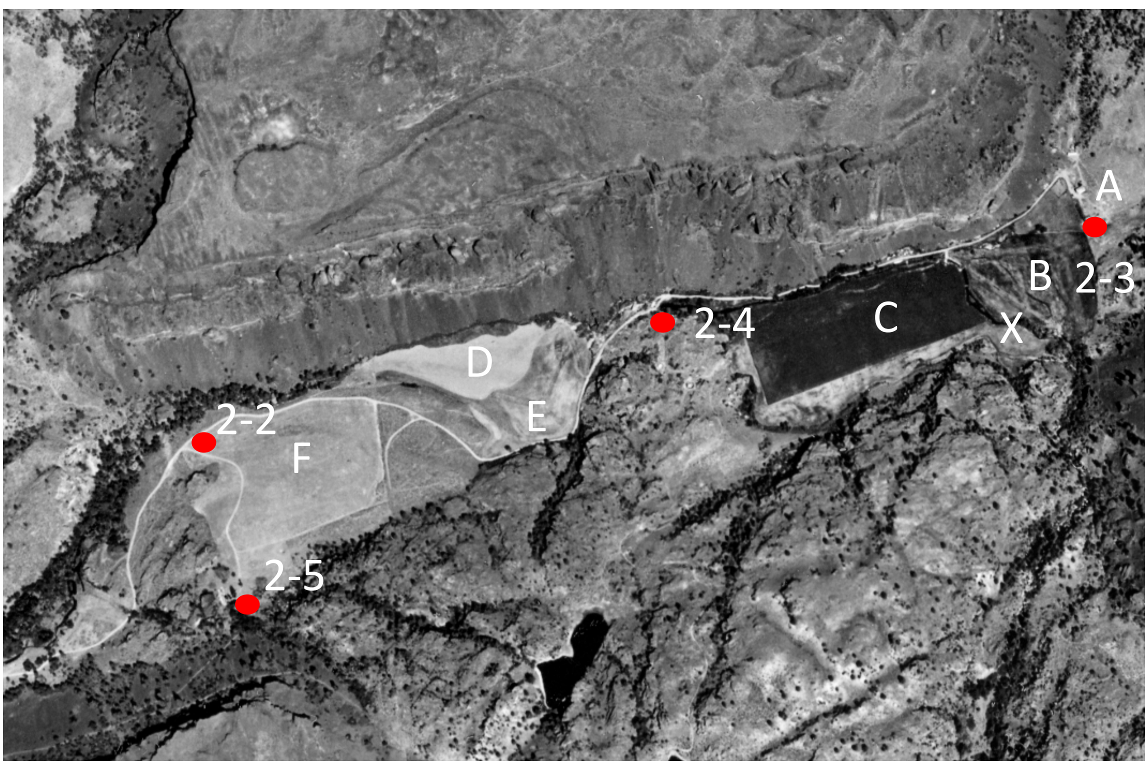


Figure 2-11. Vertical aerial view of agriculture in Northrup Canyon in the mid-1950's. Image shows at least six different farm fields: A) newer house site; B) site of former irrigated garden & orchard; C) crops (alfalfa?) irrigated by Northrup Creek (X); D) bare field—not currently irrigated; D) subirrigated hay; and F) non-irrigated pasture. Red dots and associated numbers indicate Source: USDA—Commodity Stabilization Service AAR-2P-19, June 11, 1955 available in the Central Washington Historical Aerial Photograph Project (https://www.cwu.edu/geography/central-washington-historical-aerial-photograph-project).

Stop 2-4: Northrup Creek Bridge

Where are we? We are located on the granite knobs overlooking Northrup Creek and the Northrup Creek bridge about 0.5 miles downstream of the Northrup homestead (Figure 2-1) (47.873064°N, 119.062090°W).

What is the source of Northrup Creek? Northrup Creek originates 4.3 miles east of here, flowing nearly 1.6 miles west to terminate in Banks Lake. Throughout its path, it is *underfit* indicating a much bigger stream created this large valley. The underfit nature of Northrup Creek, combined with the presence of several large flood bars, suggests an Ice Age flood origin for this canyon (Figure 2-1). Northrup Creek originates at springs below a series of scabland wetlands and lakes formed in closed depressions created by those Ice Age floods (Figure 2-4). Initially, the creek flows across the basalt scablands. Some of the flows of the floods apparently coalesced to form the easternmost of the Northrup Canyon channels. Further west, Northrup Creek's channel follows the contact between Columbia River Basalts and the older granitic rocks. Southeast of us, Northrup Creek leaves the geologic contact and erodes through granite creating an impressive canyon (Figure 2-12). This brief path through, rather than along the granitics, may have followed a joint pattern (see below).

Why does the granite terrain look so different from that of the basalts? Most of the Ellensburg Chapter IAFI field trips occur in basalts. Here, we are blessed to have granite as well as basalt. As an intrusive igneous rock, granite cooled beneath the earth surface as opposed to at Earth's surface like basalt. As a result, it cooled slowly developing large crystals so we say it is *coarse textured*. It also means that it cooled under immense pressures. These two characteristics—slow cooling and cooling under immense pressure—give intrusive igneous rocks distinct differences from basalts when it comes to weathering.

Here's how it works: first, coarse textured rocks generally weather faster than fine texture rocks. Second, the feldspars in the granitic rocks weather via *hydrolysis* to form clays. The loss of the feldspar weakens the rock structure resulting in a *granular disintegration* of the rock surface. The combination of these helps form the rounded appearance of granitics that we see here. Coarse sand and fine gravel also come from this making the typically coarse soils of such terrain.

The release of the immense pressure of overlying rock leads to the expansion of the underlying granitics. In this case, the overlying basalt was stripped off by Ice Age floods. With the resulting granitic rock expansion, successive sheets of granite separate along *sheeting joints* from the underlying bedrock in a process known as *exfoliation*. Exfoliation over time creates rounded, dome-shaped features. Such features abound within Northrup Canyon. While I have explained above how such features could have formed in the ~15,000 years since the last floods through Northrup Canyon, they may also be features formed in the long interval between the intrusion of the granitics and the deposition of the Columbia River Basalts. In the latter case, we could refer to the granitic domes as *palimpsests*, a term used in geomorphology to refer to features that developed early, were partially changed, experienced further development, were again partially weathered and eroded.

Orthogonal (i.e., right angle) *joints* also characterize granites. Joints are linear fractures in rocks along which little or no displacement occurs. In other words, they may look faults but they haven't moved like faults. Such joints form at an angle to the plane of greatest stress (Tridale and Romani, 2005). Such stress may be local or regional in scale and come from different directions; therefore, orthogonal joints commonly intersect. Orthogonal jointing is common in granitic rocks, and this is also true of the granitics in Northrup Canyon (Figure 2-12). Northrup's linear joints range from inches to tens of feet wide. They often intersect. They form linear depressions on the landscape where water may flow, ponds may form, or sediment may collect. Hidden Lake occupies the depression of one such joint (Figure 2-12)

Stop 2-3: Northrup Creek Bridge

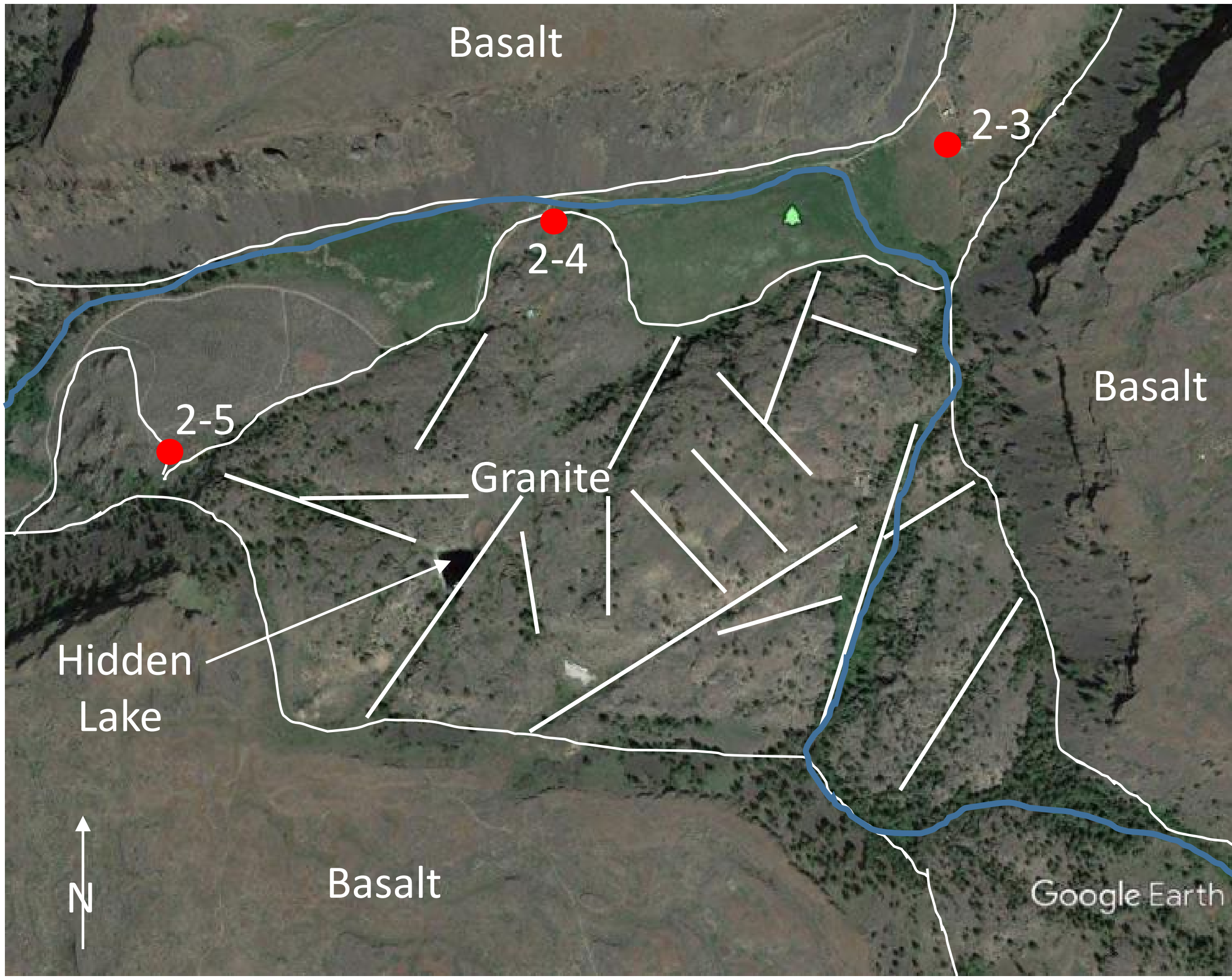


Figure 2-12. Vertical aerial view of joints in the Northrup Canyon granitics. On the ground, joints are often seen as low spots formed from the weaker zone in the rock. Note the intersecting nature of some. Source: Google Earth.

Where to next? From here, we will follow the road downcanyon to the first road off to the left (south) onto the large flood bar. This portion of the hike is about 0.6 miles. We will follow that road to the southwest end of the flood bar and the Scheibner Homestead.

Stop 2-5: Scheibner Homestead

Where are we? We are located at the Scheibner homestead on the southeast end of the large flood bar (Figure 2-1) (47.869209°N, 119.070408°W).

What is the linear depression that parallels the road to the homestead site? This is the *fosse*, the depression created by turbulence in the Ice Age floodwaters between the granitic bedrock and the bar. Because of the turbulence, little sediment is deposited there.

What's the source of the large boulders here? Large basalt boulders are present at this old homestead. Looking up to the south, a basalt talus apron blankets the canyon wall. The large boulders, like the talus apron, are the result of rockfall. And given that the talus mantles an Ice Age flood-shaped coulee wall, they formed after the floods. It is common for the largest boulders to reach the bottom of a slope and beyond because they have the greatest potential energy.

Why would someone live here? The coulee wall and surrounding trees would have provided needed shade from the sun in the summer months, and the trees and large rocks would have provided protection from the wind. Summer here could also be moderated by the presence of cold air that often flows out of the base of taluses. Given the wet nature of the slope, water would be available for domestic, livestock, and irrigation purposes. On the downside, a homestead here wouldn't get much sun in the winter and the flood bar soils likely were not especially fertile or deep.

Who lived here? This is the Scheibner homestead tucked against the talus on this north-facing slope. Charles Scheibner came to the canyon soon after John W. Northrup in 1892. He established a farm here that was known for its strawberries, fruit trees, and garden. Apparently, the farm was on the large flood bar or perhaps in the fosse, and was irrigated by a flume that delivered water from a spring above (Thompson, 1975). Scheibner produce was so desired that they hauled it by wagon to Almira or Hartline where it could then be loaded onto the train headed to Spokane (Washington State Parks, 2010). At least one of the fruit trees remains (Figure 2-13) as do water pipes likely used for irrigating crops or watering domestic animals. The dilapidated structure here is the Scheibner home which dates to about 1895 (Figure 2-14). Unlike the Northrup homes, this was built entirely of sawn lumber.

What was the source of the sawn lumber? With its Eastside forest, Northrup Canyon represented the nearest timber supply to early settlers in the Upper Grand Coulee. Northrup Creek was a ready water supply for much of the year. The combination of timber and water resulted in development of a sawmill along lower Northrup Creek by the Charles Scheibner family. Much of the sawn lumber in the Scheibner house likely came from that mill. The precise location of the mill is unknown. However, Scheibner family descendants have described it as having a tapering sluice that led to an overshot wheel. The Scheibners would dam the creek at night to build up water above the sluice. In the morning, the water would be turned loose to turn the overshot wheel which, in turn, drove the circular sawblade. They could cut logs as long as there was sufficient water. Eventually, sawdust from the mill affected the flow of the creek and adjacent springs, and the Scheibners were taken to court. A judge subsequently ordered the mill shut down and the dam removed (Washington State Parks, 2010).

Where to next? From the Scheibner homestead, we will ascend the talus for about 0.2 miles on an old road to a point where it joins the Scheibner Grade.

Stop 2-5: Scheibner Homestead

Figure 2-13. Fruit tree at Scheibner homestead site. Source: Karl Lillquist, April 2019.

Figure 2-14. Remains of the Scheibner homestead house in a stand of quaking aspen. Source: Karl Lillquist, April 2019.

Stop 2-6: Scheibner Grade

Where are we? We are located at the junction of the road coming up from the Scheibner homestead and the Scheibner Grade (Figures 2-1 & 2-16) (47.867740°N, 119.072817°W). Welcome to former Douglas County Road Number 337!

How did humans travel through Northrup Canyon? Northrup Canyon appears to have long been a transportation route connecting the Grand Coulee to the plateau above. Native Americans passed through the canyon as did Hudson Bay Company personnel travelling from Fort Okanogan to Fort Colville and Spokane House beginning in the 1820's (Anglin, 1995). The first written record of Northrup Canyon as a transportation route is from missionary Samuel Parker who noted that in 1835 his party descended the plateau via a "ravine" to reach the Grand Coulee (Parker, 1990). It is assumed that this ravine was Northrup Canyon (Anglin, 1995). The United States Exploring Expedition in 1841 also appears to have taken the Northrup Canyon route out of Grand Coulee to the east based on the description: "*They left the Grande* [sic] *Coulee by passing up the east cliff or bank, at a place where it was accessible for horses, and which as much stained with sulphur"* (Wilkes, 1845, p. 437). Perhaps this sulfur was the bright yellow lichen so common on the coulee walls. Early travelers through the area referred to the Northrup Canyon route as the Point Trail (Scheffer, 1950). Given all of this history, it is interesting that Lieutenant Thomas Symons (1881) of the U.S. Corps of Engineers apparently did not recognize Northrup Canyon as a key passage from the Grand Coulee to points east during his explorations in the region in 1879-80 (Steele, 1904).

What is this road on the talus? Because of the need to get his farm produce and lumber to market, Charles Scheibner needed a road. Others saw similar needs as well as a way to get provisions and mail from the rail stops to their homesteads. In 1901, Charles along with 26 other homesteaders in the area, petitioned Douglas County (now this area is part of Grant County) for a road to connect the Steamboat Rock-Northrup Canyon area to the plateau to the east. Subsequently, a smaller group headed by Scheibner built a ~4000 foot long road up the steep coulee slope to the plateau above. The road was completed by July 1902 and became Douglas County Road Number 337 (Luttrell, 2009). The road was most used from 1902 until the early 1930's. It was constructed for horse drawn wagons. Constantly falling rocks and a hairpin turn made it a dangerous road. At least one horse-drawn wagon and a Model T were wrecked on that slope (Thompson, 1975; Normal Northrup, personal communication, February 2014). Dangers, constant maintenance, the onset of motor vehicles, and the development of other roads in the area eventually made the Scheibner Grade obsolete (State Parks, 2010). It does not show on a 1933 map (Metsker Map Company, 1933) and by 1950 it was described as having "been abandoned for many years" (Scheffer, 1950).

We are walking on the remnant of this road. Imagine the work that went into building it across a talus slope in a time of less mechanization and more manual labor. Rock would have been moved from the upslope to the downslope edge of the road bed, and carefully stacked by hand. Once constructed, it must have required nearly constant maintenance because of *rockfall* and *talus creep*.

Where to next? This is the last stop! We will follow the Scheibner Grade back to the main canyon floor road and the parking lot.

Stop 2-6: Scheibner Grade

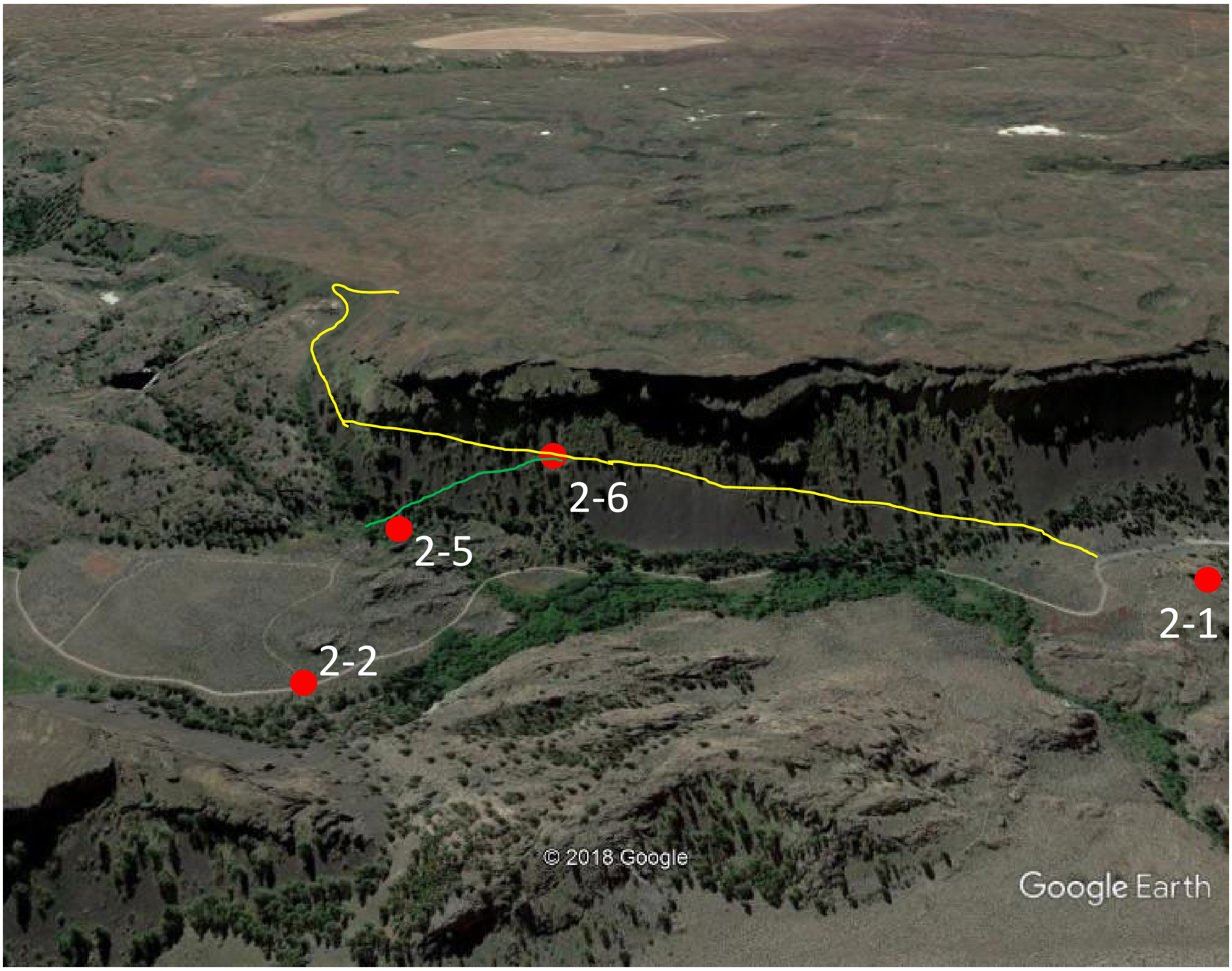


Figure 2-16. Oblique aerial view of Scheibner Grade (yellow line) and connector road (green) on the south wall of Northrup Canyon. View looking south southeast. Red dots indicate stop locations. Source: Google Earth.

Figure 2-17. Family descending Scheibner Grade in around 1911. Source: Coulee Pioneer Museum and http://www.justgetout.net/Okanogan/post/Northrup-Canyon

Stop 2-5: Scheibner Homestead & Grade

What is the chronology of development of the Northrup Canyon area?

Mesozoic and early Cenozoic (~252-~34 million years ago)

- *Granitics emplaced*

Early Cenozoic to mid-Miocene (~34- ~16.5 million years ago)

- Granitics weathered and eroded

Miocene (~16.5-~15.5 million years ago)

- Columbia River Basalts cover area

Late Pleistocene (~20,000-~15,000 year ago)

- Large floods scour area including top of plateau above
- Floods headwardly erode Upper Grand Coulee just past current canyon mouth
- Floods headwardly erode Northrup Canyon
- Floods headwardly erode through divide into Columbia River Valley
- Okanogan Lobe covers area including headwaters of Northrup Canyon

Latest Pleistocene & Holocene (~15,000-present)

- Weathering of granitics
- Weathering & mass wasting of basalts
- Native Americans travel through and perhaps permanently occupy canyon
- Fur trappers, explorers, and government surveys travel through canyon
- Homesteaders enter canyon
- Canyon abandoned
- WA State Parks, US Bureau of Land Management & Bullitt Foundation cooperate to add Northrup Canyon to Steamboat Rock State Park

Wrap-up

Nearly 200 years after its first mention, the Upper Grand Coulee continues to fascinate us. And it continues to change. This is a place that was shaped by early granitic intrusions, weathering, erosion, and extrusion of extensive basalt flows. In more recent geologic time, Ice Age floods scoured the basalts partially exposing the underlying intrusives and created the Upper Grand Coulee and associated tributaries. Late in the flood story, a large glacial lake deposited fine textured sediments on the floor of the Upper Grand Coulee. Native Americans travelled through and likely occupied the area, at least seasonally. More recently, fur trappers and explorers used the Grand Coulee and Northrup Canyon as travel routes. Homesteaders farmed the coulee floors congregating around the limited springs, streams, and lakes in the area. Contemporary humans have filled the Ice Age lake floor with Banks Lake, a 27 mile long reservoir used to irrigate the Columbia Basin Project, and have declared a significant part of the area as a state park.

Thanks for supporting the activities of the Ellensburg Chapter Ice Age Floods Institute. I hope you have enjoyed your time with us this weekend. If you have questions or comments about this field trip feel free to contact me at karl.lillquist@cwu.edu or (509) 963 1184.

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