

FRIENDS OF THE PLEISTOCENE PNW CELL - FIELD TRIP GUIDE - SEPT 2023

Calcrete Connections Across Geomorphic Domains: Channeled Scablands, Yakima Fold Belt & Palouse Hills

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Abstract

This field guide explores the spectacular calcretes of south-central Washington. The thick, bright white CaCO₃-rich paleosols overprint the Pliocene Ringold Fm, Plio-Pleistocene fan conglomerates, pre-Wisconsin flood gravels, and early Palouse loess. The blanket-like hardpans formed in alluvial sediments low in the landscape where strong evapotranspiration moved large volumes of water through the soil column via vegetation rooted near the water table. The aridity necessary to precipitate CaCO₃ arrived no earlier than 7 Ma, during the very latest Miocene and earliest Pliocene. The shift toward cooler, drier conditions was driven in part due to a newly-risen Cascade Range and leeward rain shadow and in part due to changes in ocean circulation. Growth of thick ledges occurred mostly during the Pleistocene (~2 Ma to ~50 ka) with accelerated development during interglacials. Calcretes described in this field guide span three important geomorphic domains: Palouse Hills (loess deposition), Channeled Scablands (cataclysmic flooding), and Yakima Fold Belt (young tectonism). They interfinger with sediments of each and are interwoven into their geologic histories. Though the calcretes described here are confined to a brief period of time and a thin slice of the stratigraphic column, their limited presence helps constrain paleotopography in a landscape cut by large, active faults.

Thank you trip leaders: Lydia Staisch, Bruce Bjornstad, Scott Burns!

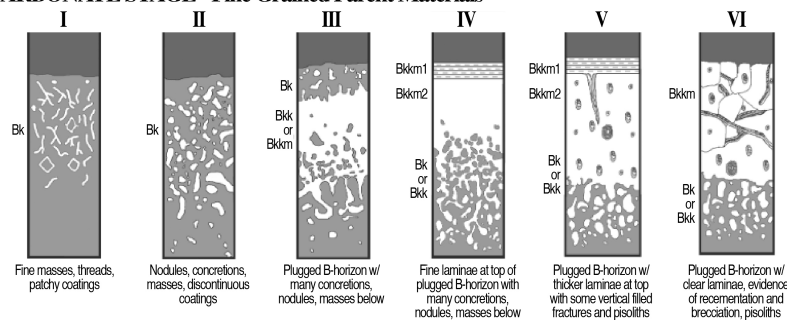


What is calcrete?

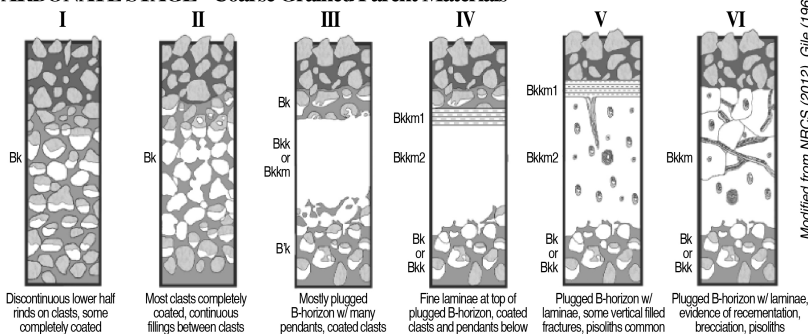
Calcrete is a CaCO_3 -rich hardpan deposit commonly found in dry, geomorphically-stable desert regions of the world (Lamplugh 1902, Gile et al. 1966, Machette 1985, Birkeland 1999, Alonso-Zarza and Wright 2010, Zamanian et al. 2016). It is a secondary precipitate formed in the rooting zone (soil B-horizon) of drought-tolerant plants like sagebrush and commonly appears as a crust on cobbles. The accumulation of pedogenic (soil-formed) carbonate occurs at the interface between atmosphere, geosphere, hydrosphere, and biosphere and involves the interplay of evapotranspiration, microbial activity around roots, the water table, soil $\text{pH} > 7$, and fluctuations in the partial pressure of CO_2 . In the Columbia Basin, which lacks a bedrock source for calcium (i.e., limestone), Ca^{2+} is leached from minerals in wind-deposited dust; loess contains feldspar and mica. The dissolved calcium is transported downward into the soil profile by rainwater or snowmelt.

Inorganic carbon and oxygen complete the CaCO_3 molecule. Rooting zone respiration by roots and microbes as well as root decay supplies CO_2 (carbon dioxide) or HCO_3^- (bicarbonate). Respiration and incomplete flushing of dryland soils concentrates CaCO_3 where it re-precipitates as calcrete, typically between 15-50 cm depth. Once formed, calcrete hardpans are remarkably resistant to erosion and dissolution. In Eastern Washington, calcretes are both pedogenic (formed in soils) and products of lateral throughflow within the soil profile and at slightly deeper levels near the water table (capillary fringe) (Slate 2000, Medley 2012, Cooley 2022).

CARBONATE STAGE - Fine Grained Parent Materials



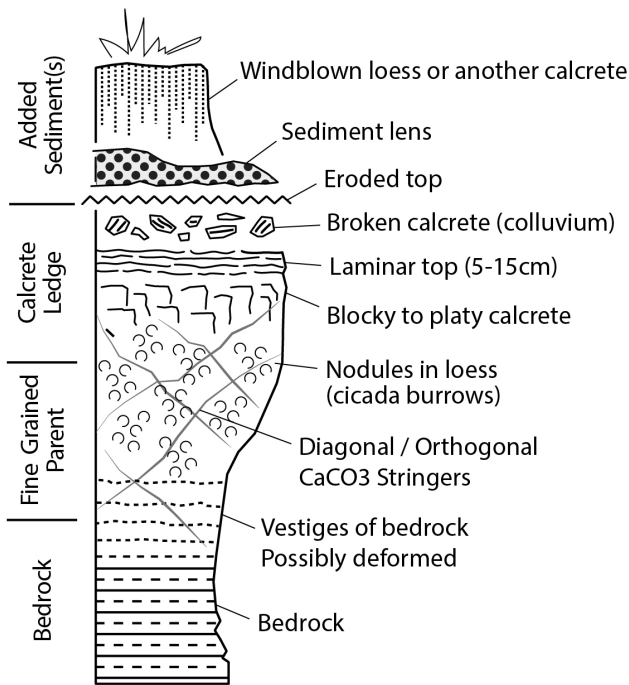
CARBONATE STAGE - Coarse Grained Parent Materials



Carbonate stage system. The relative age of calcrete is determined in the field using clues from its morphology. The Carbonate Stage system identifies six stages of development (I-VI) that progress along slightly differently lines depending whether the parent materials are fine grained or coarse grained. Its not a perfect system, but has proven to be an exceptionally useful one over the years. Calcrete morphologies differ considerably from playa evaporites (calcite, gypsum, table salt). Figure modified from Schoeneberger et al. (2012), Gile (1966), Machette (1985), and Birkeland (1999).

Pliocene aridity & rise of the Cascade Range

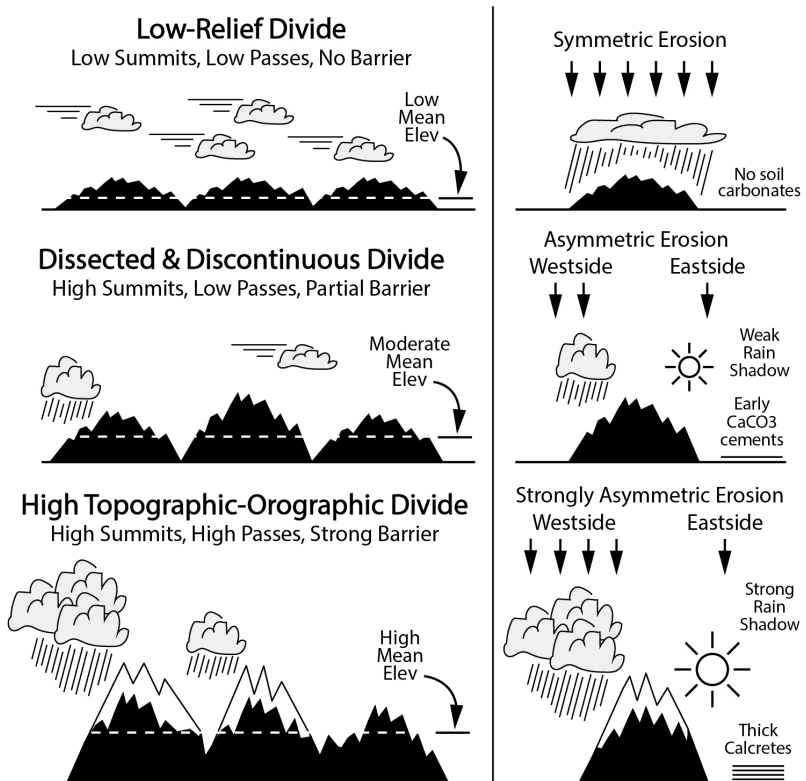
Calcrete paleosols are a dryland phenomenon. They indicate semi-arid to arid conditions and are tied to specific parts of relict landscapes. The obvious first question is therefor ‘When did a sufficiently dry climate first arrive in Eastern Washington?’ Let’s begin with the Cascade Range. The Cascades began to grow about 42 million years ago with the establishment of a convergent plate margin along the west coast of North America. The rock record indicates the North Cascades of Washington - the portion



Calcrete ledge. Several variations on this theme exist in the study area. The tops of most ledges are truncated by erosion and buried by sediments of one kind or another. Lens-shaped bodies of sediment commonly separate stacked ledges. A-horizons are rarely retained. Parent materials include loess, fan gravels, flood deposits, and lakebeds.

north of Snoqualmie Pass - achieved a height sufficient to begin partially blocking moisture-laden Pacific storms from tracking inland sometime between 12 and 6 Ma (Reiners et al. 2002, Takeuchi and Larson 2005). Signs of a proto-rain shadow, if you will, early and weak. Plant fossils from White Bluffs indicate a strong Cascades rain shadow was in place by ~5 Ma when the last few savannah-adapted hardwood trees were replaced entirely by a semi-arid sagebrush-steppe (Mustoe and Leopold 2014). Carbonate cements first appear at the tail end of CRB volcanism, during the Miocene-Pliocene transition.

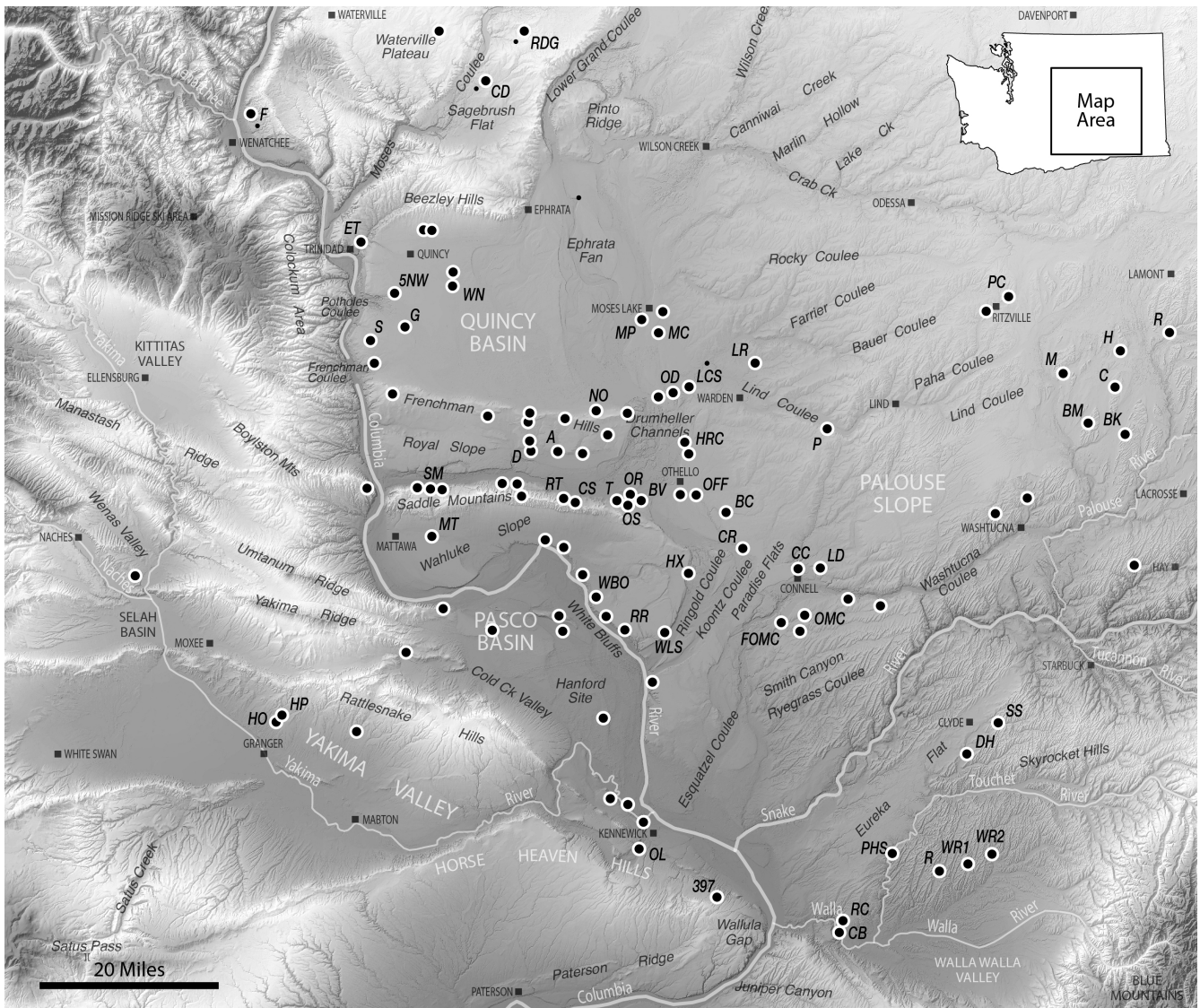
What's weird is the disparity between the start of subduction-related mountain building at the plate margin (Oligocene) and the arrival of a rain shadow east of the mountains (Pliocene). Plate convergence, topographic rise, and leeward drying should have been coincident, but it appears they were not. Formation of a high-elevation Cascades crest and a strong orographic divide appears to have lagged behind rock uplift by some 30 million years, possibly due to high erosion rates through



Miocene
 Warm, wet climate
 Weather systems unimpeded by topography
 High erosion rate across Cascade Range
 Summit heights remain low
 Sediments shed to basins to east and west
 Range-crossing valleys

Pliocene
 Cooler, drier climate
 Rising topography begins to block weather
 Moderate erosion to west, lower to east
 Sediments shed to basins to east and west
 Deep, range-crossing valleys
 Some calcic soils and cements form

Pleistocene
 Colder, wetter w/ glacials & interglacials
 Volcanic cone building
 Glacial buzzsaw at upper elevations
 Erosion high west & central, low to east
 Topographic rise of Cascade Range
 Strong rain shadow cast to east
 Fewer range-crossing valleys
 Vigorous calcic soil development



Study area. Calcretes are thickest in northern Pasco Basin, a long-lived structural low that gathered big rivers, basin-fill sediments, big floods, alluvial fans, and groundwater. ABCD = Saddle Mountains Ridge, CLS = Corfu Landslide Overlook, CO = Coyote Ck, CR = Coyan Rd, ET = East Trinidad, F = Fancher Bar, G = George Landfill, H = Harder Rd, HRC = Herman Railcut, HX = Hendricks Rd, LD = Lind Rd, LR = Leisle Rd, M = Marengo, OFF = Offramp, OMC = Old Maid Coulee, OR = O'Brian Rd Railcuts, OS = Orchard Scarp, PC = Pacific Rd, PHS = Plucker Historical Sign, R = Rulo, RC = Reese Coulee, RR = Ringold Rd, RT = Red Tank, WBO = White Bluffs Overlook, WLS = Watt Ln Landslide, WN = Winchester Canal, WRI/WR2 = Winans Rd, 5NW = White Trail Rd/Rd5NW.

the warm, wet Miocene, which kept the mean elevation of the crest low. Difficult to say, given findings to date. Nevertheless, climate in Eastern and Western Washington first diverged quite late in the Cenozoic Era, somewhere around 5 Ma.

The rain shadow cast east by the Cascades' northern segment may differ from rain shadows cast by other segments. Structural segmentation of mountain ranges seems to matter, especially in view of the larger archive of Neogene paleoclimate for the Pacific Northwest. Records from other Cascades rain shadow regions contrast with those for south-central Washington (Hammond 1979, Kohn et al. 2002

Retallack 2007, McLean and Bershaw 2021). The reader is encouraged to review these articles. To my eye, the data confirm a.) the Cascade Range is not structurally monolithic, b.) each segment has its own uplift history, c.) rock types, topography, sediments, and soils differ markedly from segment to segment, and d.) climate records associated with each segment should be evaluated separately. There is no one ‘Cascade Range’ found in the rock, soil, climate, or fossil record and I find no good reason for geologists to continue to assert there is. If there’s any question whether the range is segmented, cross the North Cascades from Newhalem to Mazama via Hwy 20, then cross the Oregon Cascades from Albany to Sisters via the Santiam Hwy and tell me its the same mountain range. Abundant volcanic rocks east of the various divides might be the only thing they share in common.

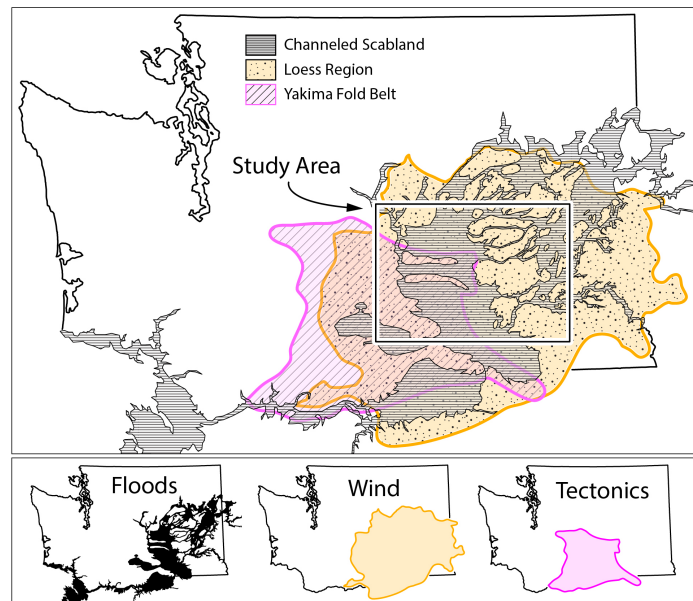
Global-scale changes also influenced the timing of the arrival of aridity to Eastern Washington. Worldwide, the Miocene (20 - 5.3 Ma) is recognized as an exceptionally warm, wet period. The Pliocene (5.3 - 2.6 Ma) in contrast was much cooler and drier. In fact, climate today closely resembles the middle Pliocene. Pliocene cooling and drying is attributed to changes in the physical configuration of ocean basins, which circulate heat. Closure of the Isthmus of Panama around 4 Ma isolated the Pacific from the Atlantic and climates across adjacent continental landmasses responded accordingly.

Columbia River Basalt & Ellensburg interbeds

Bedrock in south-central Washington is Miocene Columbia River Basalt. This field trip deals mostly with the Elephant Mountain 10.5 Ma, ($M_{V_{sem}}$), Pomona (12 Ma, $M_{V_{sp}}$), Priest Rapids (14.5 Ma, $M_{V_{wpr}}$), and Roza (14.9 Ma, $M_{V_{wr}}$) flows. Sedimentary interbeds that occur between basalt flows are composed of mixed terrigenous alluvial sediments and colorful soils mapped as either Miocene Ellensburg Fm or Latah Fm. The Ellensburg Fm comprises a lithologically-diverse wedge of sediment shed east off the Cascades that both interfingers with and overlies the basalt. Its a widespread unit and a bit of a catch-all formation. Though present in the field area, Ellensburg is not abundant and not a central focus of this guide. However, the spectacular Cougar Point Tuff (11.8 Ma), remarkably thick and baked by the overriding Elephant Mountain flow, deserves a visit.

Ringold Formation

The Miocene-Pliocene age Ringold Fm (9.5-3.4 Ma) lies atop the youngest basalt flows and represents continued infilling of the same structural basins that gathered sediments during Ellensburg time. For the most part, Ringold sediments partially fill the Pasco Basin as it was configured during the Pliocene. The uppermost Ringold is most important to our outing, as it forms the base of most calcrete-bearing sections we will visit. The Ringold

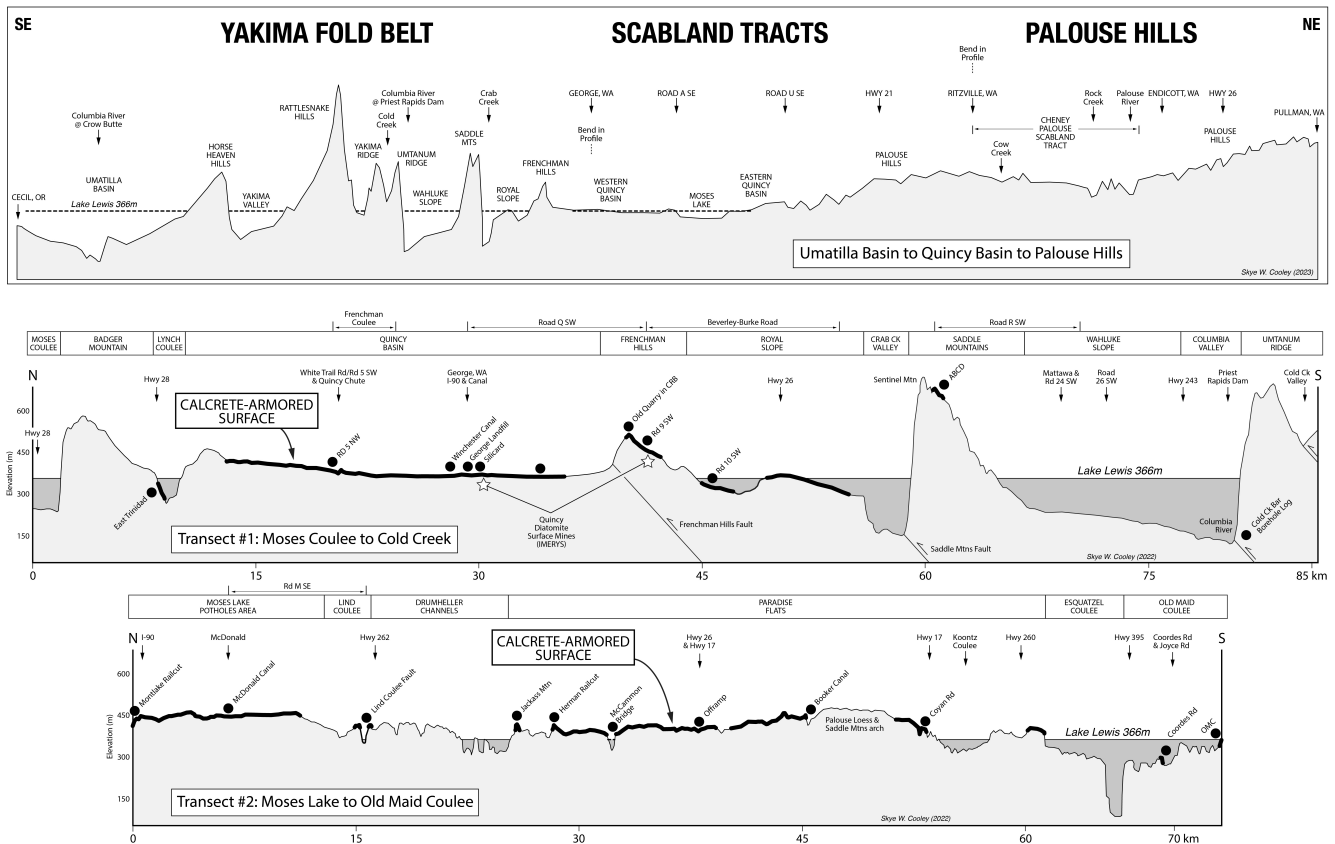


Geomorphic domains in Eastern Washington. Calcrete overlaps portions of the Yakima Fold Belt, Channeled Scablands, and Palouse Hills. Ledges of the blanket-like hardpans are thickest near Othello, a long-lived structural low. Calcrete interfingers with sediments of each domain and is interwoven into the geologic history of each.

consists of tuffaceous fluvial, overbank, and lacustrine sediments with numerous paleosols marking periods of land surface stability or lake shoaling during maturation of the broad, low floodplain of the ancestral Columbia River near its confluence with the ancestral Salmon-Clearwater-Snake Rivers (Fecht et al. 1987, Lindsey 1996, Staisch et al. 2018). The formation is up to 150 m thick and is often divided into three informal members based on sedimentological characteristics and facies associations (Lindsey 1996). Other systems for subdividing the Ringold exist, but this one still makes sense.

Savage Island	Lacustrine, sluggish fluvial, paleosols	~4.5 - 3.4 Ma
Taylor Flat	Sandy, gravelly fluvial	~5.5 - 4.5 Ma
Wooded Island	Fluvial gravels	< 9.5 Ma

Tephros (Staisch et al. 2018), vertebrates (Gustafson 1978, Smith et al. 2000), plant fossils (Mustoe and Leopold 2014), paleomagnetic data (Packer and Johnston 1979, Pluhar et al. 2006), detailed stratigraphy (Lindsey 1996), and crosscutting relationships have helped constrain the age of the Ringold to ca. 9.5 - 3.4 Ma. Ringold-equivalent basin-fill units are mapped in the Dalles syncline of



Topographic profiles and surfaces warped, incised, and buried. Regional profiles highlight the topographic expression of the Yakima Fold Belt, Channeled Scablands, and Palouse Hills. The calcrete-armored surface (heavy black lines) is deformed across Yakima Fold Belt uplifts and eroded away in coulees cut by Ice Age floods. The armored surface resisted erosion best on broad flats where waters spread out and near the elevation of maximum flooding (Lake Lewis shoreline = 366m). Upper profile: Umatilla Basin to Palouse Hills. Middle profile: Moses Coulee to Cold Creek Valley. Lower profile: Moses Lake to Old Maid Coulee. Black dots are my study locations. Figures from Cooley (2022) in Tobacco Root Geological Society Guidebook Vol. 51.

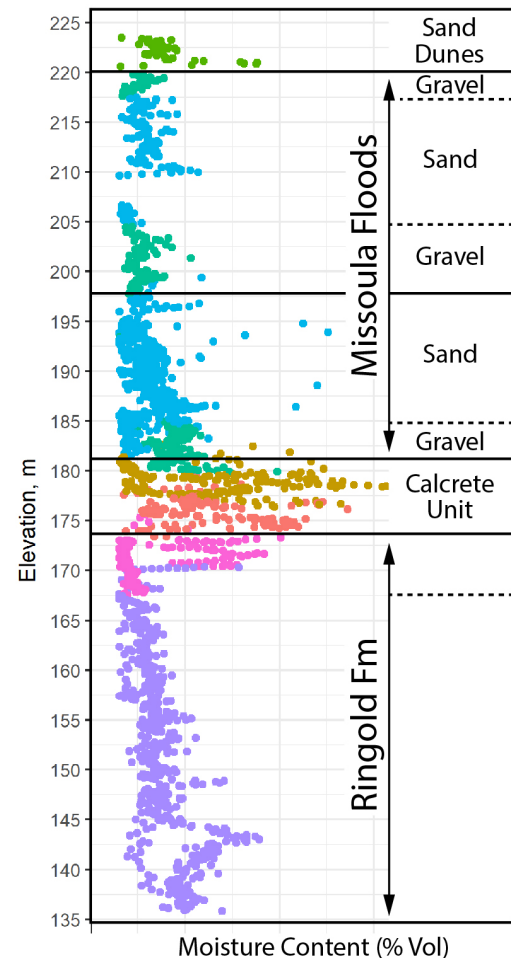
northeastern Oregon and elsewhere along the Columbia Gorge below Wallula Gap (Farooqui et al. 1981, Tolan and Beeson 1984). A full section of Ringold exists nowhere in outcrop, but large, accessible exposures along the White Bluffs are continuous over >30 km. Numerous other road, rail, and stream cuts in and around the Pasco Basin provide us a good look at the Taylor Flats and Savage Island. Pliocene deposits other than Ringold are almost entirely absent elsewhere in the Columbia Basin, according to published maps.

Post-Ringold unconformity

The top of the Ringold is truncated by an irregular unconformity formed following a base level drop on the Columbia River around 3 Ma (Brown 1959, 1960, Grolier and Bingham 1978, Lindsey 1996, USDOE 2002, 2010, Cheney 2016, Staisch et al. 2021). As much as 100 m of Ringold strata has been removed in some locations, but deep incision is certainly not the case everywhere. Distinctive laminated siltstones of the Savage Island Member, deposited near the end of Ringold time, are well preserved at White Bluffs, at Saddle Mountains, and elsewhere around the greater Pasco Basin. Calcrete overprints strata truncated by the unconformity at numerous locations.

Plio-Pleistocene calcrete

The calcrete-bearing interval of interest to us is a Pliocene-Pleistocene age unit up to about 25m thick. It consists of discrete layers (ledges) of advanced-stage calcrete with pedogenic and shallow groundwater morphologies. Calcrete overprints a variety of sedimentary parent materials and are welded (superimposed ledges) in places. Ledges are thickest in the Pasco Basin, a long-lived structural low. Precipitation of calcrete began in the early Pliocene and accelerated during the Pleistocene. It overprints Pliocene Ringold sediments, Plio-Pleistocene alluvial fan gravels, the post-Ringold unconformity, pre-Wisconsin ancient flood gravels, and lower levels of the Palouse loess. The unconformity and the calcrete interval are both warped across Yakima Fold Belt ridge anticlines. In a few places, ledges are tilted to near vertical and cut by mapped Quaternary faults. Calcrete is present in the subsurface in synclines between the fold belt ridges and is commonly intercepted by water and waste monitoring wells (Brown and McConiga 1960, Riedel 1988, Bjornstad et al. 2001).

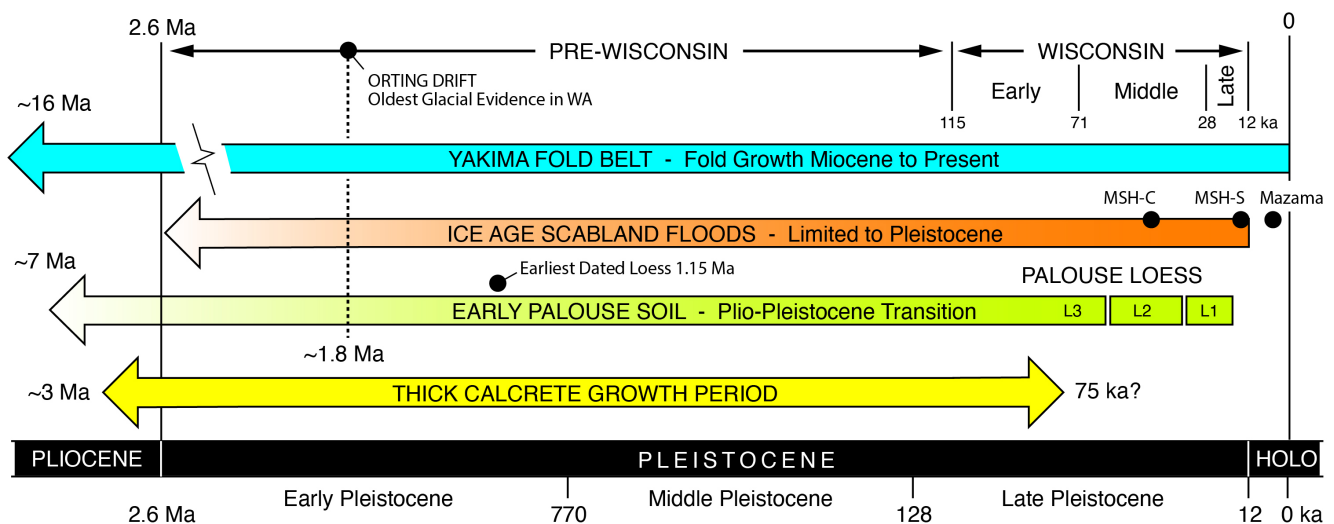


Subsurface compilation.

Compiled borehole information on geologic units beneath the the Hanford Site. The calcrete-bearing interval, Hanford's "CCU", is commonly shown separating Ringold from Missoula flood deposits. It occupies a thin, complex, and often underappreciated place in the stratigraphic column of Eastern Washington. In fewer than 25 m the unit preserves the transition from pre-glacial floodplain and syn-tectonic fan building to glacial megaflooding, loess accumulation, and calcrete growth. Modified from CP-63758.

Previous work on calcrete in Columbia Basin

Reconnaissance geologists tasked with big-picture surveying of the Channeled Scablands, Yakima Fold Belt, and Palouse Hills were quick to note conspicuous white crusts on basaltic fan gravels and in certain glacial-age deposits. In their reports, calcareous hardpans go by various names: "hard cemented light yellow alkali" (Russell 1893), "calcareous strata" (Merriam and Buwalda 1917), "caliche limestone cap" and "limestone gravel" (Bretz 1923), "lime rock zone" (Beck 1936), "calcareous layer" (Culver 1937), "caliche cap" (Newcomb 1958), "caliche cap on the Ringold" (Brown 1959, 1960), "indurated siliceous caliche" (Richmond et al. 1965), "calcrete cap" on the Ringold (Grolier and Bingham 1978), and "calcareous sand, silt, and eolian deposits" (Ledgerwood et al. 1978). A repeated phrase included in nearly every report: Calcrete is a caprock. The implication being it either formed high in the landscape or is the result of inverted relief. The correct answer is neither. We will address this question later.



Thick calcrete in context. Geologic timescale showing common subdivisions of the Pliocene and Pleistocene. While CaCO_3 cements occur in sediments older than 1.8 Ma, crosscutting relationships reveal the growth of thick calcrete ledges appears to be mainly a Pleistocene phenomenon.

Calcrete in pre-Wisconsin flood deposits

Beginning around 2 million years ago, Ice Age floods began to inundate portions of Eastern Washington. There is little preserved from very first floods that pioneered routes across the proto-Palouse, however, sites such as Herman Railcut, Harder Rd, Old Maid Coulee, George, and others show vigorous scabland floods inundated parts of the landscape hundreds of thousands of years ago and overlapped with calcrete growth (Patton and Baker, 1978, Myers and Price 1981, Baker et al. 1991, Bjornstad et al. 2001, Pluhar et al. 2006, McDonald et al. 2012, Medley 2012, Bader et al. 2016). Two ancient boulder gravels (perhaps more), both containing calcrete rip-ups, occur in the Channeled Scablands. The gravels are preserved along the eastern and western margins of the floodway region. Ancient floods left other evidence behind, too. A flight of broad terrace-like benches at Paradise Flats and sediment-floored coulees in upper Ringold-Koontz Coulee also appear to pre-date late Wisconsin scabland. Loess-floored coulees to the north and east, near Davenport, Hooper, and Spokane were recognized by Bretz (1923 field notes, p. 59, 65, 69). He called them "semi-scab" channels "not eroded

enough to have a scabland floor” and associated them with floods released from beneath his ‘Spokane’ age ice margin. A network of abandoned scabland channels are visible in aerial images of the eastern floodway. Some pre-glacial drainages, like Lind Coulee, though widened by glacial floods, persist today and are partially refilled with mottled alluvium, rubified loess, and well-developed paleosols.

Calcrete in Palouse loess

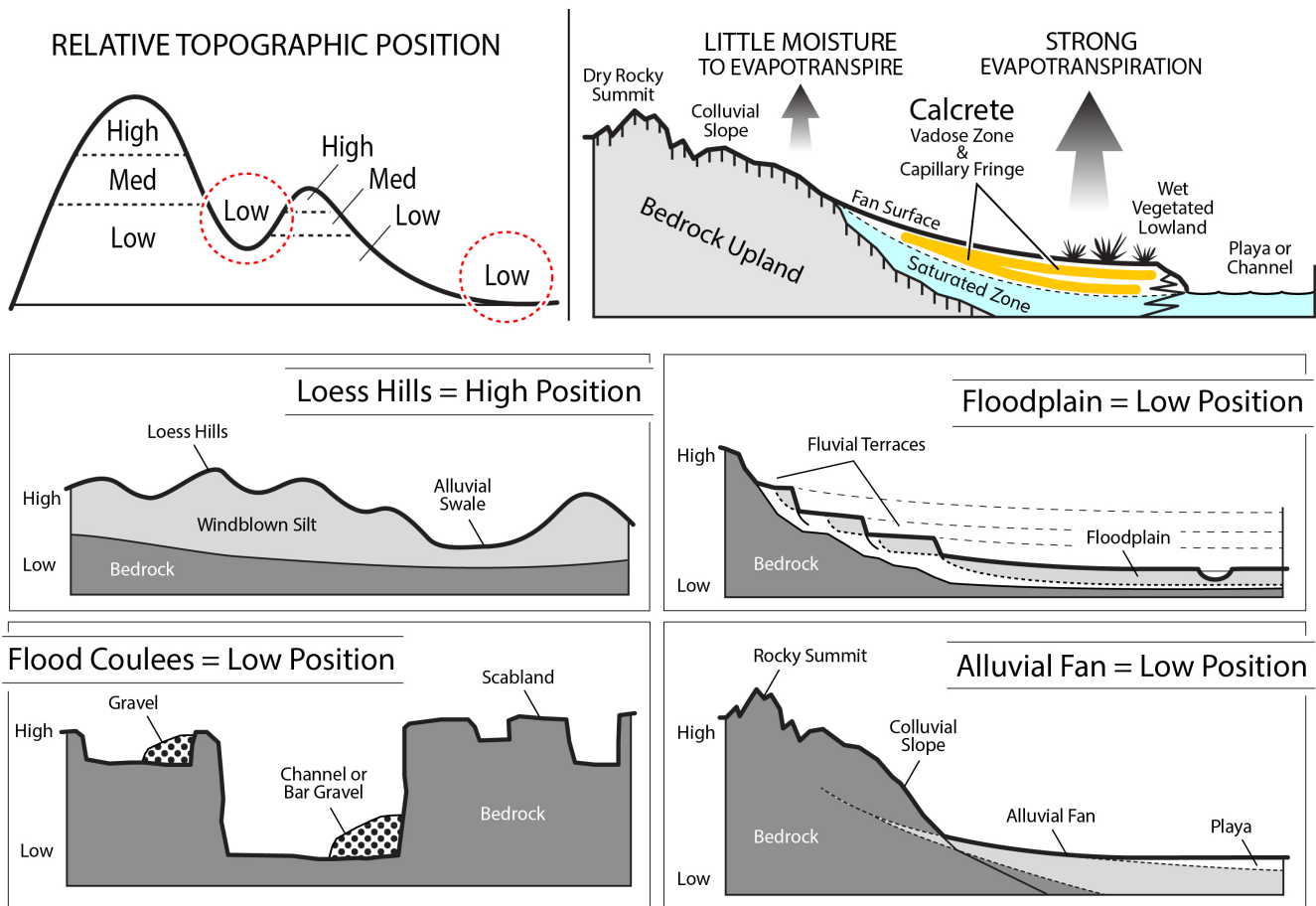
Palouse loess is windblown silt and fine sand recycled from flood-laid sediments dropped in basins to the south and west by the last glacial floods of the Missoula cycle (18 - 14 ka). It is composed of quartz, feldspar, and mica grains. Grainsize increases slightly upwind, becoming sandy near source basins.

While most of the loess in the Palouse Hills is younger than 20,000 years, layers of reddened and cemented loess (‘early Palouse loess’) exist at deeper levels. The origin of this pre-Wisconsin loess, that which predates the last glacial maximum, is less clear. Cascade tephras have played a major role in establishing a chronostratigraphic framework for Palouse loess and scabland deposits with which it sometimes interfingers. Flood-cut unconformities separate the loess into three units (L1, L2, L3 of Busacca and collaborators). The oldest tephra in the earliest loess (L3) dates from the eruption of Mt. Baker's Kulshan caldera at 1.15 Ma (King et al. 2016). Thermoluminescence (TL) dates for the L3 loess include 116 ka (Winona WIN-1) and 75 ka (Washtucna WA-5) (Richardson et al. 1997).



Pliocene loess. Little attention has been paid to pre-glacial loess west of the Palouse. This photo from White Bluffs shows a colorful paleosol interval developed in both wetland muck (gray-green) and upland loess (reddish-tan) formed along the shoreline plain of Lake Ringold during a lowstand period. Paleosols here correspond with shoaling and internally record the transition from mostly-wet lowland (gray-green, clayey) to mostly-dry upland (reddish, silty, burrowed, modest Bk horizons). Columbia Basin was a windy, dusty place long before Ice Age floods arrived.

Both early and late loesses are wind-recycled products, but from somewhat different sources. The older loess is sourced from the floodplain of the ancestral Columbia-Snake River system (Ringold Fm) and a few other minor deposits. Pliocene loess is a thing. It occurs within the Pliocene Ringold between lakebed packages of the Savage Island member. Younger but still pre-Wisconsin sandy loess separates Plio-Pleistocene calcrete ledges, occurs in water-reworked deposits (‘silt-pebble diamicts’), encloses boulder gravels, and interfingers with fan gravels shed from basalt ridges of the YFB (‘alluvial fan-loess-calcrete complexes’). Loess deposition in south-central Washington began millions of years ago, long before the Kulshan caldera eruption and long before Pleistocene glaciers arrived in Washington. Loess deposition not only overlapped with Lake Ringold, but with pre-Late Wisconsin flooding, accelerated fan building, calcrete growth, and late Wisconsin Missoula flooding. Dust continues to fall today. As they say, ‘Palouse storms build Okanogan soils’.



Top left: Relative topographic position. Relative topographic position is the location of any element in the landscape relative to other elements nearby, independent of elevation above sea level. For example, the summit of Little Tahoma (11,138'), a satellite peak of Mt. Rainier (14,417'), occupies a high topographic position, though it is > 3200 ft lower than nearby Mt. Rainier. Likewise, a cirque valley occupies a relatively low position even though it may be perched high above the valley of the river drains the mountain range.

Top right: Calcrete needs water. Calcic subsoils (Bk horizons) form at various landscape positions due to a variety of factors, but thick petrocalcic horizons (Bkk) tend to form at lower positions where strong evapotranspiration moves large volumes of water through the soil column via vegetation rooted near the water table. Alluvial fans, fluvial terraces, dusty and sluggish alluvial plains, and the floors of flood coulees. At high, dry positions moisture is limited, thus the supply of dissolved constituents is limited. More water, not less, seems to create thicker calcretes in a semi-arid region like Columbia Basin.

Bottom: Calcrete forms low in the landscape. Floodplains are low elements (i.e., Lower Lind Coulee, Offramp, New Orchard, Orchard Scarp, Watt Ln Landslide, Hendricks Rd, White Trail). Alluvial fans emerging from mountain fronts are low elements (i.e., Saddle Mts, Smyrna Bench, Red Tank Hike). Scabland coulees are low elements (i.e, Herman Railcut, George, White Bluffs Overlook, Harder Rd, Ringold Rd Bluffs Hike, Old Maid Coulee). Loess hills of the Palouse occupy medium to high positions, though their elevations are quite modest (i.e., Booker Rd, Lind Rd, Pacific Rd, East Trinidad, Rd G NE). Abandoned fluvial terraces occupy middle positions. In Eastern Washington, meter-thick, advanced-stage calcretes formed low in the landscape mostly during the Pleistocene.

Age estimates

Age data on Eastern Washington calcretes are incomplete. Early investigators with limited access to modern instruments, qualitatively bracketed the age of old loess, ancient flood deposits, and calcrete, employing terms borrowed from the Rocky Mountains like 'Bull Lake' and 'pre-Wisconsin'. Where on the geologic time scale to locate Washington's calcretes proved difficult back then and remained a challenge for decades. Calcrete has been lumped with the Ringold Fm on geologic maps (Schuster et al. 1997), mapped separately as a 'pre-late Wisconsin unit' (Stoeffel et al. 1991), and distinguished as a low-permeability 'geohydrologic unit' at the Hanford Site, formerly their 'Plio-Pleistocene unit' now their 'Cold Creek unit' (Lindsey 1992, DOE 2012).



Stability-instability cycle.

Windblown silt competes with soil-forming processes in the Palouse Hills, resulting in an alternating pattern of reddish loess and white calcrete described as pulsed sedimentation and laminar growth (Alonso-Zarza et al. 1998). Calcrete layers in late Wisconsin Palouse soils are thin, but numerous. Where the western Palouse Slope meets the Pasco Basin, calcrete layers begin to thicken, often matching that of loess beds.

Crusts on bedrock - CaCO_3 cementation in south-central Washington post-dates eruption of the Columbia River Basalt. Carbonate-silica crusts overprint an eroded, weathered surface atop the 10.5 Ma Elephant Mountain and 12 Ma Pomona flows. These deep cements do not appear to be soil-formed (pedogenic). Rather, they are groundwater precipitates formed above impermeable bedrock. They may be coeval with or significantly younger than the rocks they cement, but no younger than about 7 Ma (very latest Miocene) due to rain shadow aridity. Meters of sediment vertically separate the Miocene crusts from thicker, younger calcretes that overprint fan-loess complexes (i.e., Maughan Ranch sites).

Pliocene loess - Pedogenic carbonate occurs in two prominent paleosol zones in the Pliocene-age Savage Island member of the Ringold Fm (< 4 Ma).

Floods & loess - Calcrete cements alluvial fan gravels shed from and preserved on the flanks of YFB ridges such as the Saddle Mountains. Uplift began in the Miocene, but the structural and topographic relief we see to day above Crab Creek Valley is generally considered to have developed in pulses, the first during the Pliocene (5.3 - 2.6 Ma), a second during the Pleistocene (< 2.6 Ma). Calcrete also overprints ancient Ice Age flood gravels and silt-pebble diamicts in the Channeled Scablands (< 2 Ma). I believe these are entirely Pleistocene and pre-date late Wisconsin Missoula floods (18 - 14 ka).

Crosscutting relationships - Crosscutting relationships indicate the peak of calcrete growth occurred between ~1.8 Ma and ~50 ka. Early to middle Pleistocene calcretes commonly appear as 1-3 resistant ledges atop pre-Wisconsin boulder gravels or layers of sandy-pebbly, oxidized loess between. Welded

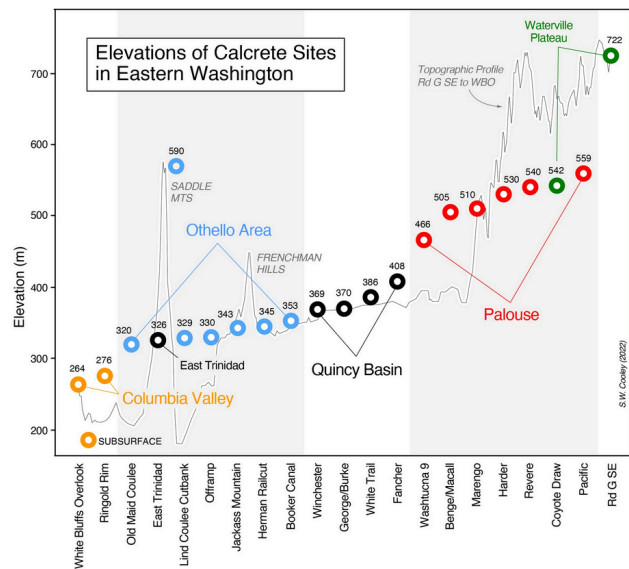
contacts between ledges occur where sediments pinch out. Welding can sometimes obscure contacts between ledges in the field (Ruhe and Olson 1980). Calcrete ledges are nearly always buried, preserved beneath younger flood deposits, loess, sand dunes, or alluvium.

Thermoluminescence - Fecht et al. (1987) used a single(?) thermoluminescence date from a calcrete in Pasco Basin to bracket regional incision of the ancestral Columbia River to between 3.4 - 2.0 Ma. Details of that study remain cryptic. Nevertheless, the date provided an important limiting age for end-of-Ringold sedimentation. The TL date showed the Ringold system shut off before the onset of the first Pleistocene glacial, a finding that contrasted with earlier interpretations. Up to that time many believed lakebeds in the upper Ringold were deposited during the Pleistocene (i.e., Strand and Hough 1952).

Fossils & Tephra - Abundant vertebrate fossils in the Ringold broadly confirm geologically-determined ages (Gustafson 1974, 1978, 2012, Smith 2000). Plants fossils identify significant ecological shifts during Ringold time (Mustoe and Leopold, 2014). A tephrochronology for the Taylor Flat and Savage Island, fan-loess complexes, deep Palouse loess, and pre-Wisconsin scabland deposits (e.g., Plio-Pleistocene section) has been partially worked, but is not as clearly synthesized as that for late Wisconsin Missoula flood deposits and Palouse loess (L1, L2). A new paleomagnetic survey of the upper half of the Ringold would provide much needed clarity.

Paleosols - Soils information is instructive. Paleosols, most often calcrete, cap ancient flood deposits in the Channeled Scablands (Bretz et al. 1956, Richmond et al. 1965, Patton and Baker 1978, Busacca et al. 1989, Baker et al. 1991, Bjornstad et al. 2001, Spencer and Jaffee 2002, Bjornstad 2006, Baker et al. 2016, Waitt 2017). Calcrete and silcrete horizons have been carefully documented in the Palouse Hills using soil taxonomy (Busacca 1989, McDonald and Busacca 1992, McDonald et al. 2012, Sweeney et al. 2017). Informal age bins (L1, L2, L3 loess) are used in some of these authors articles for Palouse paleosols.

Absolute age data - Quantitative age data is found in several recent studies have improved age control on Eastern Washington calcretes. Medley (2012) quantified carbonate content in calcretes sampled in the Channeled Scablands using a Chittick apparatus. She found morphologies consistent with Stage III development or greater (i.e., tens of thousands of years old) at 15 of 25 sites. U-series ages ranging from 44,000 to 669,000 ka are reported for calcretes in the Pasco Basin and adjacent Saddle Mountains (Bjornstad et al. 2001, Pluhar et al. 2006, Staisch et al. 2018). Sample collection has been a bit haphazard (i.e., random roadcuts, deformed groundwater crust, rhizoliths in cemented loess). U-series dating, specifically the uranium-thorium



Elevated calcrete. Between Waterville Plateau/Hwy 2 and White Bluffs Overlook, the calcrete-armed surface more or less follows valley topography with one notable exception: Point #590 atop Saddle Mountains. Calcrete there is elevated some 500 m above adjacent Crab Ck Valley by faulting.

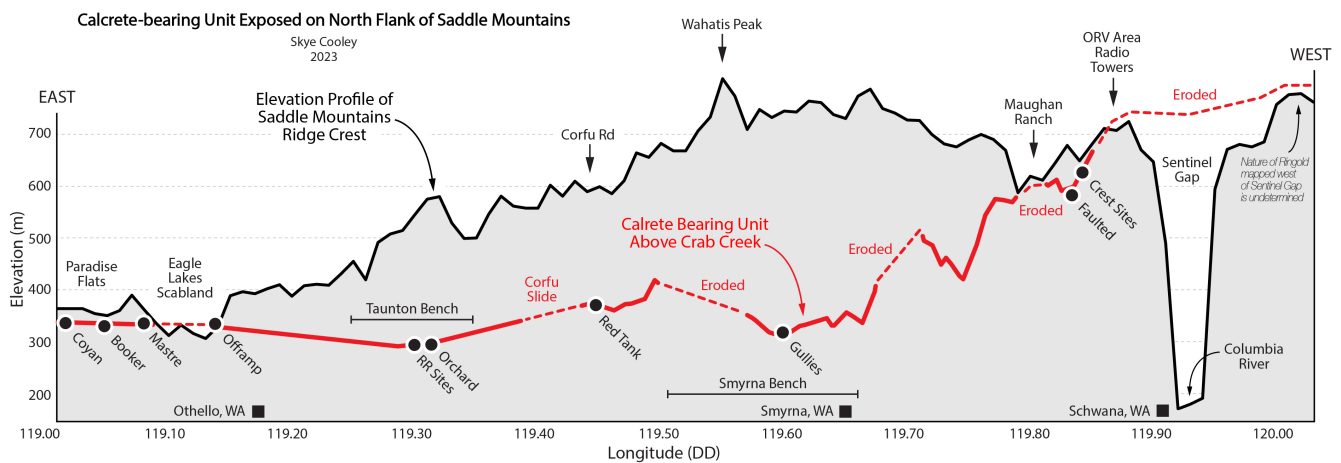
method (U-Th), has generally proven reliable for carbonates up to ~500,000 years old. Older samples are subject to open-system effects. Open-system behavior is inherent to vadose zone soil carbonates and known to diminish the accuracy of U-series results (Alonso-Zarza and Tanner 2010). Several of the samples analyzed in the aforementioned studies exceeded the 500,000-year limit, therefore reported U-series ages on Columbia Basin samples are probably best considered age minimums. Though additional dates are needed, it is clear that some Columbia Basin calcretes exceed 200,000 years and some appear to pre-date the Brunhes-Matuyama magnetic reversal at 780,000 years (Bjornstad et al. 2001).

Limits on calcrete distribution

Calcrete is not found everywhere in Eastern Washington. Factors that retard calcrete growth include 1.) rapid sedimentation and/or burial, 2.) erosion, 3.) high rainfall. Continuous, rapid sedimentation (rapid aggradation) suppresses horizonation in dust-dominated soils. Soil processes are swamped by addition of new material. Soil processes beneath a deeply-buried surface are reset to the new surface. Erosion lowers the ground surface by stripping material, which also resets the soil profile to a lower position, deeper below where it had been. Rainfall in excess of about 28 in/yr effectively flushes CaCO₃ from soil profiles before it can become calcrete. Once formed, however, the same amount of precipitation cannot dissolve calcrete at the rate it formed. Just as today, burial, erosion, and rainfall flushing conspired in the past to restrict calcrete growth to specific areas: low, hot basin centers traversed by large rivers and bordered by low-angle fans.

Land surface stability: Competition between burial, erosion & soil formation

A stable soil surface is one that is neither buried or eroded too quickly. Examples of geomorphically stable surfaces are prairies, river terraces, large alluvial fans, and marine terraces. Mature paleosols, especially where stacked, are a mark of long-term surface stability. The Palouse Hills is known for its stacked paleosols. The Palouse Hills are convex and relatively dry. Most soil profiles with caliche horizons developed above the water table on upland hillslopes. Caliche stringers and minor ledges are common in soil series such as the Thatuna, Oliphant, and Santa. Windblown dust accumulation rates



Line across the mountain. The calcrete unit follows a nearly unbroken line for 75 km across the north face of Saddle Mountains, gently rising to Sentinel Gap and beyond. It caps intermediate benches, traverses rocky slopes, and occupies the ridge crest itself. To the east the unit armors Paradise Flats. To the north portions of Royal Slope and Quincy Basin. To the south, the White Bluffs.

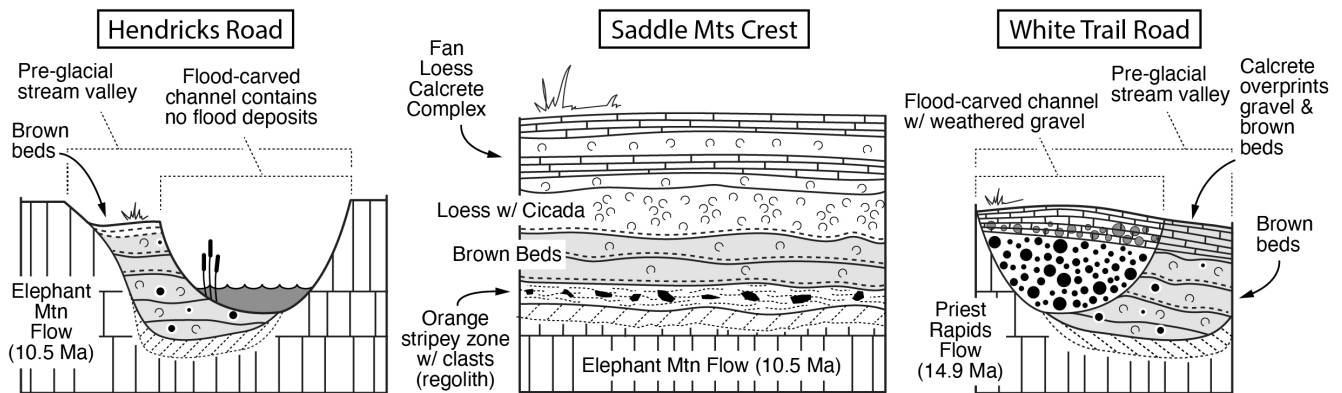
across the Palouse have remained high, if somewhat variable, over millennia. Consequently, calcrete ledges like those near Othello did not form in the Palouse. Calcrete cannot achieve a full, thick expression in the Palouse because sedimentation rates out-compete soil formation. The competition between burial (surface instability) and soil development (surface stability) is best seen at stops such as Booker Road, Lind Road, and Marengo.

Landscape position

One of the most important aspects of the calcretes - unmentioned in previous articles - is their close association with alluvial deposits and formation in lowland settings. Calcrete in the Columbia Basin nearly always grew into sediments of a broad, gently-undulating floodplain and low-gradient alluvial fans that graded to it. Ledges grew thick in close proximity to the water table and a seasonally-fluctuating capillary fringe that supplied ample water to soils and plants. Low landscape positions, abundant water supply, and thick calcrete go hand in hand. If there's doubt, consider the converse. High landscape positions (i.e., ridge crests, convex hillslopes, etc.) are dry, steep, and tend to shed rather than accumulate water and sediment. Dense communities of cicada, grasses, and sagebrush generally don't live there. The so-called 'capping calcretes' today exposed atop the Saddle Mountains and White Bluffs were formed in a valley and were later elevated by faulting.

Contiguous, crusty & recently deformed

The calcrete-armored surface beneath the town of Othello can be traced west as a nearly contiguous line across the south face of Saddle Mountains to at least Sentinel Gap. Because few detailed investigations have been made, many believe the calcrete unit atop Saddle Mountains (ridge setting) to be something quite different from the unit at Othello, George, Liesle Rd, and Moses Lake (valley

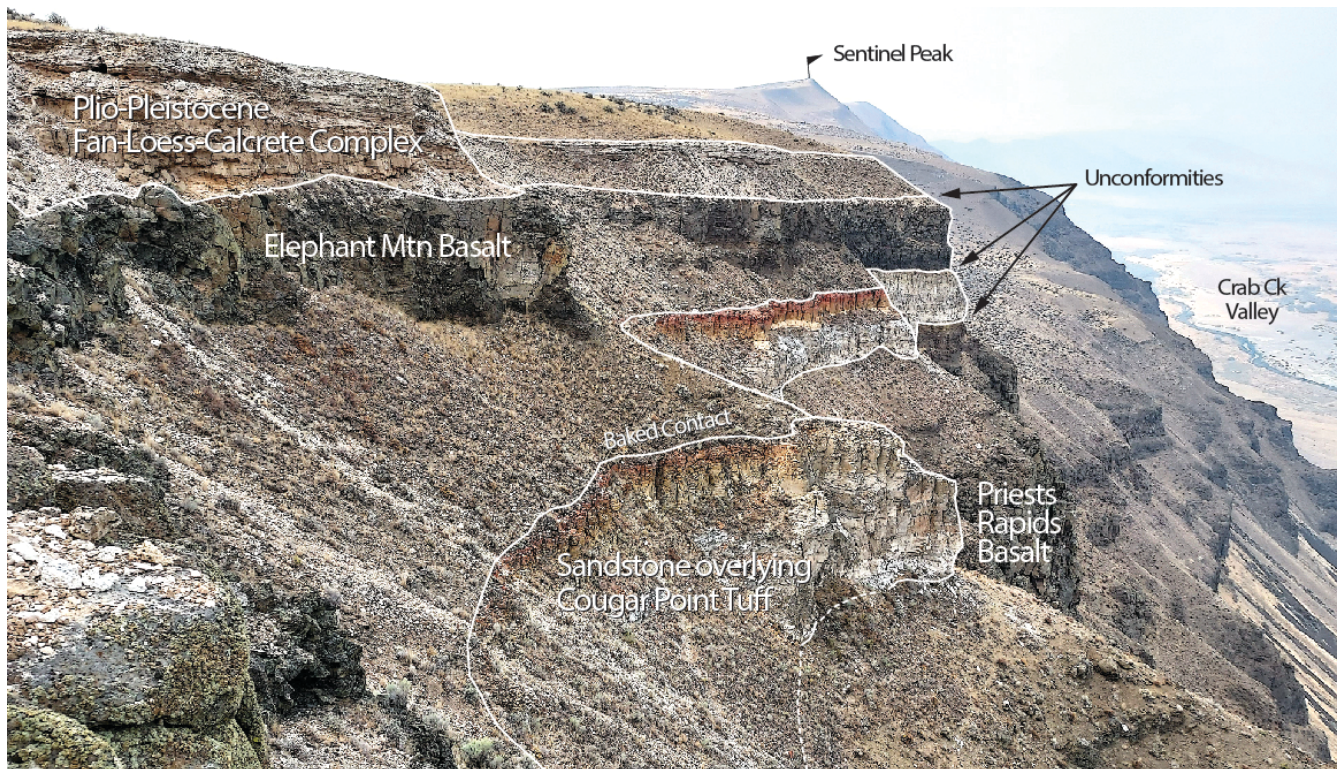


Continuity across folds. Calcrete-capped beds of brown alluvium occur at three widely-separated locations atop weathered basalt. The brown beds are the alluvium of pre-glacial streams. White Trail (385m elevation) and Hendricks Rd (246m elevation) sites are located north and south of the Saddle Mountains anticline (600m elevation). The same beds occur atop the crest of the fold, hundreds of meters higher. Calcrete at White Trail overprints a pre-Wisconsin flood gravel and the brown beds, indicating cementation is Pleistocene in age similar to calcretes at Herman Railcut, Offramp, George, White Bluffs Overlook, Old Maid Coulee, and Harder Rd. Calcrete at Hendricks road has been partially removed by late Wisconsin floods. At Saddle Mountains, the brown beds are overlain by complex of low-angle alluvial fan gravel-loess-calcrete coeval with calcretes at Othello, western Palouse Slope, White Bluffs, Royal Slope, Quincy Basin, and Wahluke Slope. Brown alluvium on flat-lying basalt is consistent with a low-relief landscape. Calcrete that overlies pre-Wisconsin flood deposits and underlies early Palouse loess armors a low-relief surface that has been warped by younger tectonism and incised by late Wisconsin floods.

position). However, a simple elevation plot of calcrete exposures from the Waterville Plateau to Pasco Basin reveals it follows the same geomorphic surface and constitutes the same crust. Blanket-like calcrete defines a formerly contiguous surface formed at a low elevation in valley alluvium and valley-adjacent fans mostly during the Pleistocene. The crusted surface, which approximates the post-Ringold surface, was deformed by young faults in the Yakima Fold Belt.

Summary

Calcretes in south-central Washington are thick, widespread, and visually stunning. These resistant and well-preserved soil carbonates have helped constrain incision by the ancestral Columbia River, date local tectonism, identify pre-Missoula megaflood deposits, and refine the stratigraphic framework for the Palouse. Pedogenic calcretes highlighted in this field guide constitute an important, but largely ignored sedimentary interval (a marker unit) that spans the region's three geomorphic domains: Palouse Hills, Channeled Scablands, and Yakima Fold Belt. The relict hardpans define a formerly low-relief paleosurface that has since been warped and faulted by Yakima Fold Belt structures.



FRIENDS OF THE PLEISTOCENE PNW CELL - FIELD TRIP GUIDE - SEPT 2023

Field Trip Stops

Additional photos and figures for field stops at www.skyecooley.com.

Herman Railcut

Two calcrete ledges, old loess, and a pre-Wisconsin boulder gravel atop Ringold lakebeds

46.8844, -119.1508

Directions - From Othello, drive 4.5 miles north on Hwy 17. Turn L (west) onto Herman Rd. There is no left turn lane here, so be careful. Drive 1 mile west on Herman Rd, cross tracks, and park at the bottom of hill in a wide pullout. From the rail crossing, hike south moving behind the stack of old ties on a gently rising traverse up the sagebrush slope toward a small shrubby tree in the distance. Stay above the wet ditch that parallels the tracks. At small tree, drop down beneath ledge. Ledges and sediments beneath exposed for a few hundred meters south. Weedy and buggy in late summer. I discovered this site in March 2018. Please limit disturbance of gravel and rock sampling.

Description - The railway runs along an escarpment at the outer bend of the Drumheller Channels scabland (Crab Creek Valley). The butte-and-basin topography of Columbia National Wildlife Refuge are visible to the NW. This location was at the margin of high energy, erosive flows and miles away from the Saddle Mountains and Frenchman Hills ridges.

A boulder gravel, overprinted by calcrete, rests directly atop truncated Pliocene lakebeds (Savage Island Member) and is overlain by two more calcrete ledges. I interpret the gravel as a pre-Late Wisconsin flood deposit. Calcrete that overprints the gravel shows evidence of lateral throughflow (subhorizontal movement of solutes). In the gravel, look for chunks of green-gray Vantage sandstone, white Ringold mudstone, and other non-basalt clasts. The upper two calcrete ledges are separated by beds of nodular loess (upland deposits) and a red-brown, pebbly silt-sand diamict (stream-reworked? loess) that thins and thickens laterally. The upper calcrete is a fully plugged, Stage V carbonate well over meter thick. Its parent material is almost entirely consumed by CaCO_3 , but sparse black basalt cobbles poke out here and there. The amount of time required to accumulate the meter-thick upper calcrete alone is substantial. A conservative estimate for the age of the boulder gravel is 300,000-500,000 years.

Aridity alone does not build thick calcrete. You need a lot of water. These calcrete hardpans formed in a dusty, alluvial lowland setting, where seasonal wetting (or fluctuations in water table) alternated with longer periods of intense drying. Calcretes show evidence of growth both within soils and near the water table (capillary fringe). I suspect their growth has been accelerated due to their proximity to groundwater. The recipe for thick calcretes seems to be: Semi-arid climate + Alluvial valley position near water table + Vegetation and strong ET.



Older boulders. A flood-laid boulder gravel that truncates Ringold lakebeds is capped by two thick calcretes that interfinger with loess and silt-pebble diamict. The time needed to build the thick ledges is hundreds of thousands of years. Missoula flood gravels cap the section. Non-basaltic clasts and rip-ups of a yet older calcrete are found within. Thick CaCO_3 rinds crust some clasts. The site is located along the margin of Drumheller Channels and is several kilometers removed from both Saddle Mts and Frenchman Hills ridges.



Blocky calcrete ledge, likely welded, 1.5m thick
Floating basalt cobbles and hints of sediment lenses

Reddish lenses of silt-pebble diamict w/ sandy cicada-burrowed loess, weakly stratified, stringers



Caliche ledge with horizontal fabric overprints top of gravel which fines upward

Boulder gravel w/ sandy matrix, subangular-subrounded sandstone, fines upward, and calcrete rip-ups, cemented at top, truncates Savage Island



Savage Island siltstone, springs emerge from top locally

Offramp Site at Othello

Two thick calcretes separated by sandy nodular loess overprint Savage Island lakebeds

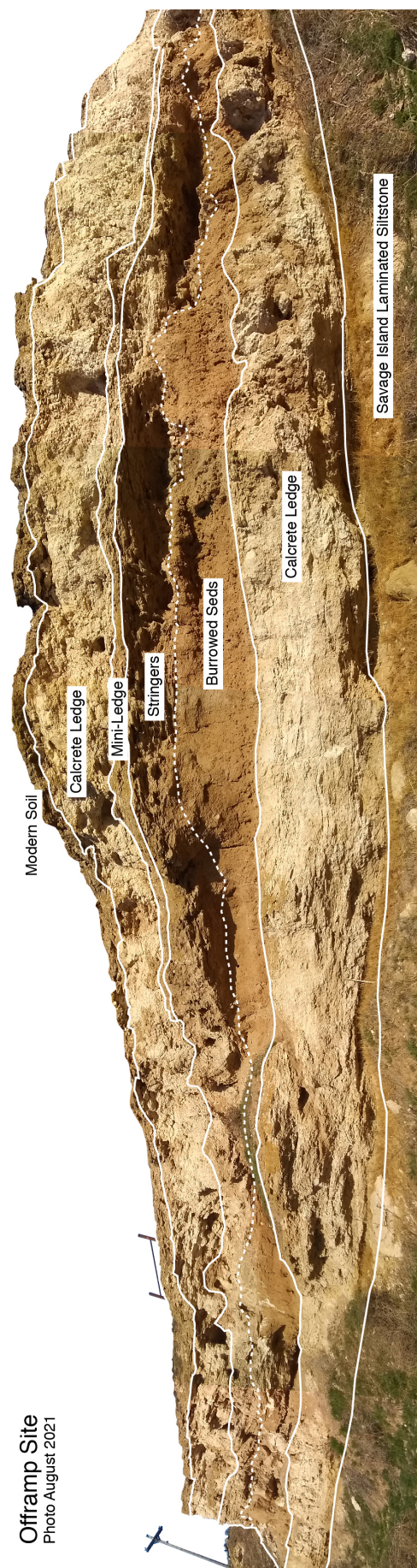
46.8097, -119.1328

Directions - The Offramp site is a canal cut located behind a hay storage lot just east of the Hwy 26-Hwy 17 interchange SE of Othello. Park along the shoulder of Hwy 26, just east of the overpass, between the hay storage lot and the northbound offramp of Hwy 17. Locate a dusty two-track leading south along the hay lot fence. Walk a few hundred meters south, cross the wire fence, and drop below the rim to canal level on an easy footpath at its north end. Footing can be loose, brushy, and seasonally wet.

Description - Two prominent calcrete ledges are separated by irregular bodies of reddish, silty-sandy sediment containing abundant soil features (carbonate stringers, root casts, and cemented cicada burrows). The red sediment appears to be wind deposited, but in places is quite sandy. The sand component suggests close proximity to a source basin, similar to Eureka Flat where proximal windblown sand sheet deposits are recognized (Sweeney et al. 2017). The sand component can be interpreted another way; it may be loess reworked by flowing water (i.e., an overland flood).

Cylindrical nodules are cicada nymph feeding burrows commonly found in Palouse soils (O'Geen et al. 2002). The 1-2 cm diameter x 3-15 cm long burrows lend a bumpy appearance. A pattern of fine, arcuate ridges formed as the advancing insect chewed through soil and cast it out, backfilling its path.

The lowest red bed occupies the same stratigraphic position as the boulder gravel at Herman Railcut. The lowest calcrete overprints flat-lying Savage Island Member (Ringold Fm) lake beds and has a hard, blocky top ~20cm thick. Displacive fabric is seen in the ledge ("inflation" along bedding planes by carbonate growth). Uncemented green-tan lakebeds are visible in small caves at the base of the exposure. The upper ledge is a fully plugged Stage V calcrete more than a meter thick. Its thickness and morphology suggest it formed near the water table (capillary fringe?).



White Bluffs Overlook

Calcrete gravel with exotic lithologies truncates Savage Island lakebeds, fluvial sands, and more.

46.6257, -119.3955

Directions - From Othello, drive Hwy 26 west for 17.5 miles to the White Bluffs Area gate. Turn L (south) and follow the gravel road for 8 miles to its end at the White Bluffs Overlook parking lot. Continuous outcrop lines the Old Ringold Road and a few other off-trail exposures to the south are accessible via short hikes and by dropping below the rim.

Description - Busloads of geologists have stood where you are standing. Most have enjoyed the views of the Hanford Reach, the impressive landslides, flood trimlines, and moth-balled nuclear reactors across the river. Geologically speaking, there is far more to see here than one might expect at first glance. The guidebooks and interpretive signs fail us. Beautifully preserved sediments of the Ringold Formation and overlying calcrete-bearing unit contain many fascinating aspects and require close inspection to appreciate. Units exposed along Old Ringold Rd include:

Savage Island Member siltstones - Laminated lacustrine siltstones of the Pliocene Ringold Fm Savage Island Member, called "buff laminated clay" by Grolier and Bingham (1978), comprise much of the exposure. The Savage Island is tan-green-white-gray siltstone. Some fizzes vigorously in acid (tan silt) or not at all (gray-green clay). Difficult to determine just how deep the lake was from clues available; my guess is < 30 m.

Loess paleosols between lakebed sections - Two colorful paleosol intervals mark shoalings of the Pliocene Lake Ringold. Look for exposures in tumbleweed-filled gullies a few hundred meters down from the parking area. Reddish nodular loess and gray-green wetland muck is found in both - very similar to sediments found in lower Lind Coulee, Watt Ln, Scooteny Rd, MarDon, and elsewhere.

Gray fluvial sands - Beds of rippled gray sand interrupt the lake deposits. The sands are mostly unconsolidated, but locally can become thoroughly-cemented with a lumpy appearance. The thin sands are products of a sluggish, relatively shallow fluvial environment, possibly distal deltaic. Convolute and swirled bedding is commonly where sand and lacustrine sediments interfinger; the deformation is symsedimentary.

Massive sandy beds - Two thick, massive beds of muddy sand are found near the lower end of the first yellow guardrail. At least four are present in the section. Their thicknesses changes across the exposure. These sandy beds (energetic flow) were deposited on the dead-flat, soupy lake bottom. They have no coarse bedload. Where thin laminae are highlighted by oxidation, swirled forms can be seen. Sometimes twisted chunks float in the matrix. Massive sand beds can be produced in several ways. What are a few possibilities? What are the sedimentary and tectonic implications of each?

Cemented white ribbons - Resistant white beds up to about 10cm thick occur in the Savage Island near the gate. The ribbons thin and thicken (boudin-like) and pinch out laterally. The thin white beds may be volcanic ash or ribbons of silica from the former lake bottom - or maybe both. How could they be both?

Post-Ringold unconformity - The top of the Ringold Fm (lakebed-sand package) is here truncated by a prominent unconformity that began to form when base level on the Columbia River dropped abruptly around 3.2 Ma. The erosional surface remains in the Savage Island, so not a tremendous amount of incision. The surface is deformed by nearby Yakima Folds and armored by calcrete. It is the local expression of a region-scale erosional surface that separates two of Washington's major packages of rocks (synthems). Synthems are unconformity-bounded sequences of rocks. Synthems provide a useful, big picture framework for our region (Sloss 1963, Wheeler and Mallory 1970, Armentrout 1987, Cheney 2016). The four Cenozoic synthems of Washington are: Challis, Kittitas, Walpapi, High Cascades. The post-Ringold surface separates High Cascades rocks (< 3 Ma) from Walpapi rocks (13-7 Ma). The surface has not been precisely dated, but it appears to be no older than 3.4 Ma and no younger than 2.0 Ma. Region-scale erosional surfaces imply region-scale tectonic events (e.g., big and important ones). In this case, an event affecting the Columbia River drainage after 4 Ma.

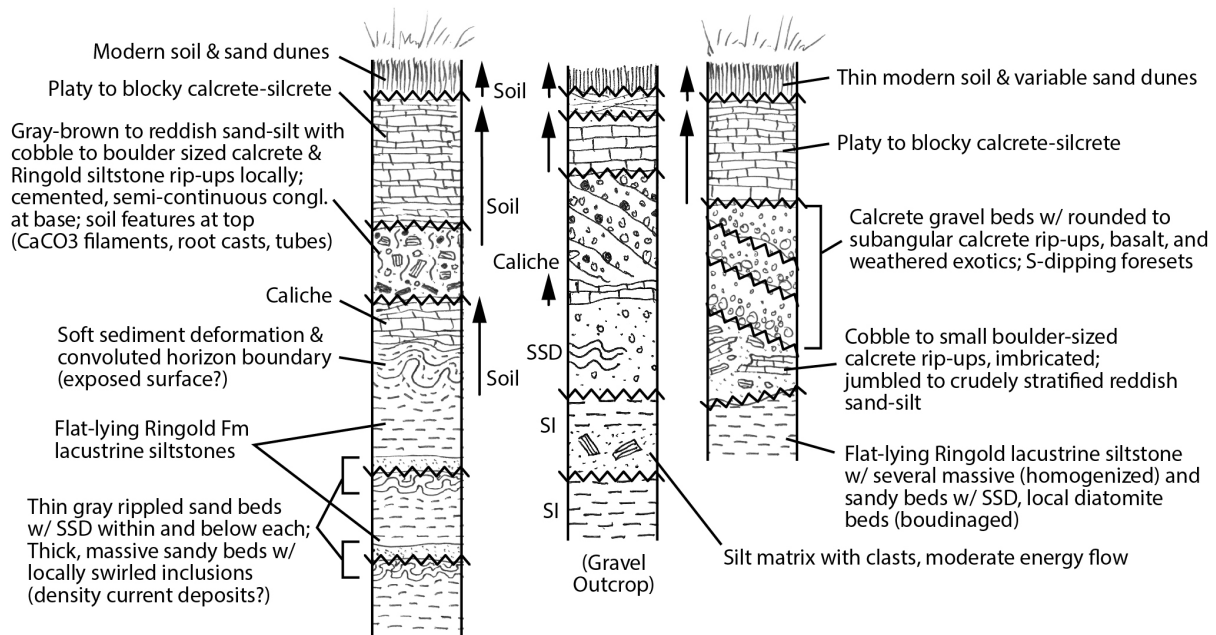
Ancient flood gravel - Between the top of the Ringold and the capping calcrete lies a reddish zone of energetically-transported material up to a couple meters thick that extends across the entire exposure. Its thickness, color, texture, and sedimentary character varies as you move down the exposure. I interpret this zone to be a pre-Wisconsin flood deposit. Several places offer a good look at the unit, but two places in particular - located at either end of the cut - reveal most of its variation.

North Location Near Gate: The reddish, massive to stratified, silty, water-lain unit contains cobble- to boulder-sized rip-up clasts of calcrete and stratified laths of siltstone. A thin, cemented, semi-continuous conglomerate occurs near the base of the unit in places.

South Location Along Bluff: The meter-thick gravel with south-dipping foresets is composed mostly of calcrete rip-ups and fewer non-basaltic clasts. A zone of reworked Ringold material lies below the gravel and a thick ledge of hard, intact calcrete lies above. Load casts and flame structures are common in strata beneath gravel. Clasts are angular to rounded, pebble- to cobble-sized. Exotic lithologies include felsic volcanics, granites, dark gray schist, vein quartz, a dark intrusive, and weathered basalts. Clasts have carbonate coatings and comprise a relatively small fraction of the gravel. Mafics disintegrate when excavated.

Characteristics are consistent with overland flooding (age, deformed base, foresets, exotic clasts), but the precise route taken by the flood is not well constrained. A flood may have come down the Columbia Valley or come from the east, over the nose of Saddle Mountains where Hwy 24 crests the grade at a saddle (Mound Rd-Rangeview Rd). Did only one pre-Wisconsin flood pass through here? Was the height of the anticline lower at that time? Were large clasts strained out? How is gravel related to the Eagle Lakes-Ringold Coulee scabland or Bjornstad's 'Channel rhythmites' to the north?

Capping calcretes - Two thick calcretes cap the bluff. The lower calcrete is a blocky, Stage III+ unit 20-40 cm thick. It was deformed and partially disaggregated by an overriding flood. The upper calcrete is a ~3m-thick, Stage V ledge-former with blocky to platy-laminar morphologies. The contact with the flood-laid unit is well defined and fairly flat. Based on its thickness, the upper calcrete is probably a stack of welded calcretes similar to that at Offramp and Herman Railcut, but the ledge is too broken up to resolve. Holocene dunes cap the section.



White Bluffs Overlook. Exotic-bearing gravels were deposited by a pre-Wisconsin overland flood that spilled across the eastern nose of Saddle Mountains toward the Columbia River. Floodwaters dislodged large stratified laths of Ringold siltstone and rip-ups of calcrete. A zone of soft sediment deformation occurs in laminated siltstone beneath the calcrete gravel.



Capping Ledges & Calcrete Gravel. Thick Pleistocene calcrete ledges (left) overlie the post-Ringold Fm unconformity and younger, exotic-bearing flood gravels (right).

Lower Lind Coulee

Thrust fault places basalt over loess w/ calcrete, some curious alluvial deposits, and an ancient gravel

48.9879, -119.2078 ← Dirt pull out parking area

Directions - From Potholes State Park/MarDon resort area, drive east on Hwy 262 across O'Sullivan Dam to Road M SE. Turn L (north) and quickly pull off into an informal dirt parking area near the south abutment of the bridge. Or continue across bridge to a large, paved, public lot with pit toilets. Either way, your goal is to traverse west along the shoreline bluffs on the south bank of Crab Creek. Low water level is essential; some amount of shoreline must be present. From the bridge, follow an informal footpath west through cheatgrass and sage along the top of the bluff, then drop down to shoreline. Boots, long pants, and bug spray recommended.

Geography: Crab Creek flows west through Lind Coulee and empties to Potholes Reservoir. Potholes Reservoir, a part of the Columbia Basin Irrigation Project, began filling in 1949 with the construction of O'Sullivan Dam across the head of Drumheller Channels, a part of Columbia National Wildlife Refuge managed by USFWS. Potholes Reservoir is filled by water from Moses Lake.

Description - Any excursion into Lind Coulee is an adventure. Here we'll see young faulting and interesting Plio-Pleistocene stratigraphy. The Lind Coulee East Fault, an eastern extension of the Frenchman Hills structure, was trenched in the late 1970s by the U.S. Bureau of Reclamation.

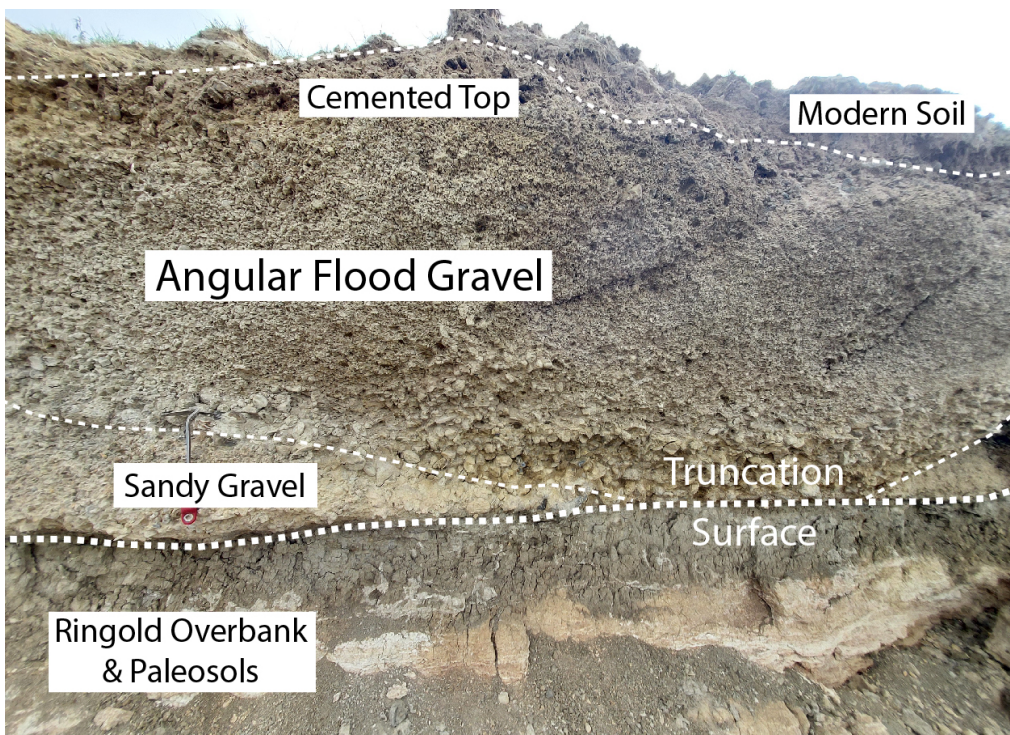
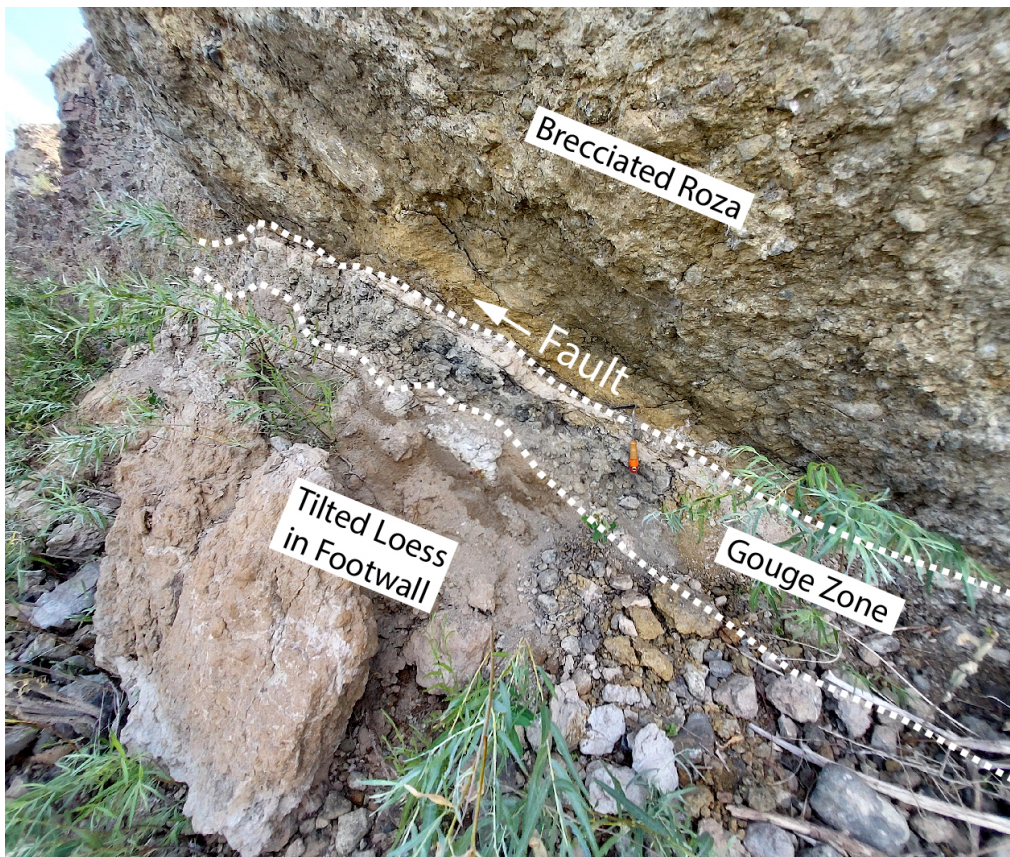
Quaternary Fault - Lind Coulee Fault is a splay of the larger Frenchman Hills structure, known to have Quaternary movement (Reidel and Fecht 1994; Schuster et al. 1997; Lidke and Haller 2016). The south-dipping thrust places Miocene Roza basalt over uncemented Palouse loess (Grolier and Bingham 1971, 1978). Michael West, consultant to USBOR, trenched the fault in a few places nearby (West and Shaffer/GEI 1988, Shaffer and West 1989, Geomatrix Consultants Inc. 1990). The fault is well exposed at the shoreline during low water periods. Shattered basalt, thin zone of white gouge, and slivers of brown mudstone are commonly observed along the fault. Competent Roza basalt is spheroidally weathered in places.

Angular flood gravel - A basaltic gravel is exposed in shoreline bluffs east and west of the Rd M SE bridge. The gravel truncates Pliocene Ringold overbank sediments and a distinctive hard, white paleosol. It is overlain by muddy, variably-cemented alluvium of ancestral Crab Creek (Pleistocene?), calcrete ledges and cemented, cicada-burrowed loess, uncemented loess, and bouldery Missoula flood deposits. I discovered the gravelly unit in 2021 and interpret it as a pre-Wisconsin flood gravel. It thickens to >1m at the WDFW fishing access area (46.9859, -119.2247). Its top is cemented.

North vs. South - Thick megaflood sands and gravels that form the north bank of Crab Ck all but disappear to the south. The south bank is boulder-strewn, scoured to bedrock in places, but gravel free.

Mazama ash - Mazama ash with backfilled rodent and insect burrows occurs with alluvium exposed in shoreline bluffs west of the bridge.

Additional reading - USBOR (1954), Reidel & Campbell (1989, Stop 21-A, Fig. 14), Reidel & Fecht (1994), Cooley (2022, TRGS v. 51).



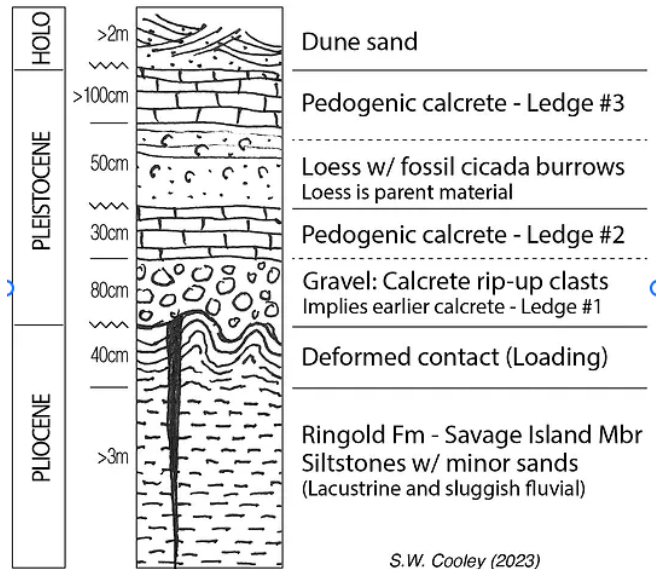
Floods and Faults. Top: Lind Coulee Fault is well exposed in shoreline bluffs along Crab Creek in lower Lind Coulee. Bottom: A slug of angular gravel truncates Ringold sediments and is overlain by alluvium and younger flood deposits. The gravel is interpreted as a pre-Wisconsin flood deposit.

Ringold Road Bluffs Hike at lower Koontz Coulee

Calcrete rip-ups and deformation at the upper and lower ends of Ringold-Koontz Coulee

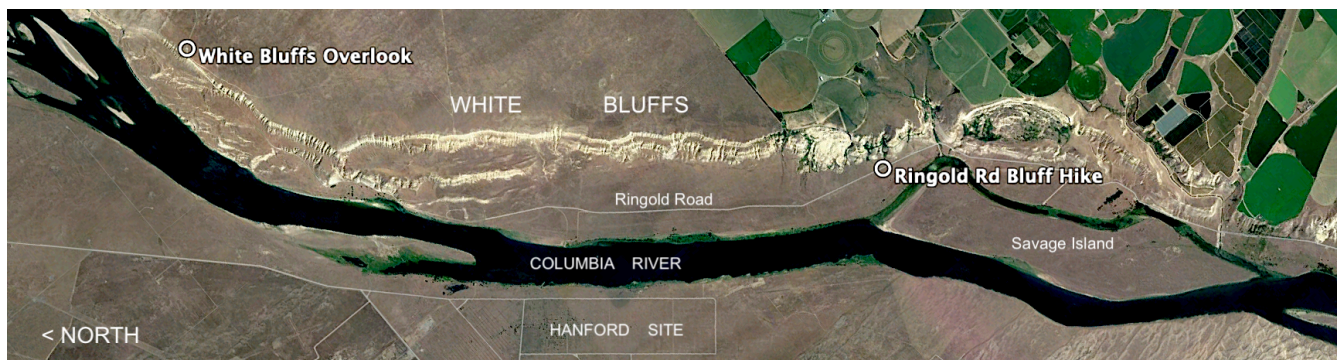
48.5687, -119.3166 ← Park vehicle

Directions - Basin City is 19 miles south of Othello on Hwy 24/Sagehill Rd. From Basin City, drive west on Rd 170. Turn L (south) onto Fairway Rd (Rd 170), which becomes W. Klamath Rd, then Rd 170 again. In a few minutes, turn R (west) onto Ringold Rd which drops to the Columbia River, then R (north) onto graveled Ringold River Rd. Drive 5.5 miles north and park on road shoulder (see map). This is federal land managed by USFWS. Leave the road and hike NE across open ground, crossing a wire fence, toward a good path leading up a nose in light colored Ringold sediments. Active landsliding is occurring along the bluffs beneath your feet. Note the network of lateral spread fractures and toppled blocks. Your goal is the white ledge of calcrete near 46.5709, -119.3107. Short traverses in either direction provide excellent views of the 2m-thick calcrete ledge. Spring and Fall are the best times to visit. The White Bluffs are blazing hot in Summer.



Ringold Rd Hike. Deformed ringold lake beds are truncated by a calcrete gravel (ancient flood deposit) that is capped by younger calcretes and loess. Cemented clastic dikes intrude the Ringold and are cut by the gravel. The same rip-up gravel and pattern of deformation occur at White Bluffs Overlook to the north and Coyan Rd to the east.

Description - Ringold Rd and Coyan Rd sites are located at the lower and upper ends of Ringold-Koontz Coulee. Though separated by nearly 30 km, their stratigraphy is remarkably similar. Calcrete rip-ups comprise gravel beds that unconformably overlie deformed Ringold lakebeds (Savage Island Member). At Coyan Rd, a contorted zone 40 cm thick is laterally traceable for over 25 m. At Ringold Rd, the same contorted zone occurs at the top of the Savage Island Member lakebeds. Cemented, downward-tapering clastic dikes descend from the erosional contact between the calcrete gravel and lakebeds beneath.



George Gravel Pit

Pre-Wisconsin flood gravel(s) of weathered basalt and exotic clasts capped by a thick calcrete

47.1004, -119.8701

Directions - George, WA is located off I-90 northeast of Vantage. Take Exit 149 for Hwy 281/Quincy/Wenatchee. Turn L (west) onto Hwy 281 and cross over the freeway. Cross a canal and turn L onto Beverly-Burke Rd, then R onto Rd 1 NW. A green metal shed will appear at the entrance to the closed and partially reclaimed landfill, a property of Grant County Public Works. Park nearby. Walk-in only. Don't be conspicuous. Respect signage.

Description - The low walls of the pit expose > 4 m of old flood gravel with south- and east-dipping foresets capped by a thick, platy calcrete. The boulder gravel (possibly two gravel units) contains deeply-weathered basalt clasts and some hard, seemingly unweathered clasts. Chunks of Vantage sandstone, far-travelled quartzite and granite, and green opal from local pillow-palagonite complexes (i.e., Silica Rd offramp) are also in the mix. Sandy loess caps the gravel. The overlying calcrete is 80cm thick with blocky to platy morphology and fully-plugged.



George is Burke. A blocky-platy calcrete caps one, possibly two, old flood gravels at George. The deposit consists mostly of deeply weathered basalt, but non-basalt clasts are also found.

Vic Baker and George Neff (Baker 1973) following Bretz et al. (1956) and Richmond et al. (1965) describe the deposit as "pre-Pinedale flood deposits" (Pinedale = late Wisconsin = Missoula floods). Floods that deposited the gravel at George pre-date Missoula floods cycle. Floodwater exited the Columbia River channel into Quincy Basin at Babcock Ridge, following an easterly route toward Drumheller Channels. In contrast, the Missoula floods spilled SW across Quincy Basin.

Hendricks Road

Brown beds of pre-glacial alluvium w/ Bk horizons atop Elephant Mtn basalt cut by younger floods

Directions - From Connell, drive W on Hwy 260, cross Hwy 17, and continue on Hendricks Rd for 7.5 miles. The roadcuts are located where Bailie Creek crosses beneath the road, a short distance past a kiosk and small parking area for Bailie Memorial Youth Ranch and Wildlife Area. An unnamed pond immediately east of the road fills a scabland basin. Park at the kiosk and walk narrow shoulder to outcrops. Do not block gated ranch driveways.

46.6744, -119.1515

Description - Roadcuts at Bailie Creek expose brown, cemented, flat-lying beds of basaltic alluvium that show no evidence of being baked by an overriding basalt flow (not an interbed). They rest unconformably atop the 10.5 Ma Elephant Mountain basalt, one of the youngest flows in the CRBG. They are pre-glacial sediments and of the Pliocene Ringold Fm. Deposits of a sluggish, low order stream flooded in basalt that empties to a broad plain of the ancestral Columbia River.



Five sandstone beds, each about 30cm thick, contain deeply-weathered basalt cobbles, cicada burrows (Pliocene), and Bk soil profiles (Stage II+ caliche). The top bed sports a notably thicker Bkk cap. Cicada trace fossils and caliche horizons indicate each bed dried out after it was deposited (channel migration? incision?). A lens of lacustrine-like sediment and a yellowish zone of weathered basaltic regolith 20cm-thick occur at the base of the exposure. Hard basalt not far below. The brown beds hunker behind a knob of resistant basalt, protected from energetic west-directed overland floods. The fact that they exist here at all, in the heart of a major scabland, is remarkable.

These same beds are found atop folded Elephant Mtn basalt at Saddle Mountains 50 km to the NW, at White Trail Rd near Potholes Coulee some 80 km NW, and possibly at lower Lind Coulee 35 km to the N. At Saddle Mts, the brown beds are unconformably overlain by a Pleistocene fan-loess-calcrete complex several meters thick.

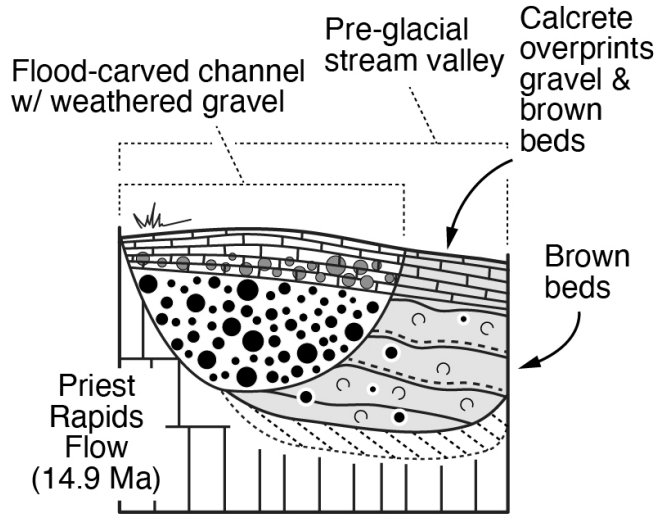
At Hendricks Rd and White Trail, the bedrock is undeformed and scoured by floods. The capping calcrete is thickest at White Trail, where it caps both the beds and pre-Wisconsin flood gravel. The same calcrete and brown beds appear at Hendricks Rd (Pasco Basin), White Trail (Quincy Basin), and Saddle Mts anticline, which separates them.

White Trail/Rd 5 NW

Brown sandstone inset into basalt is cut by a pre-Wisconsin gravel channel and capped by calcrete

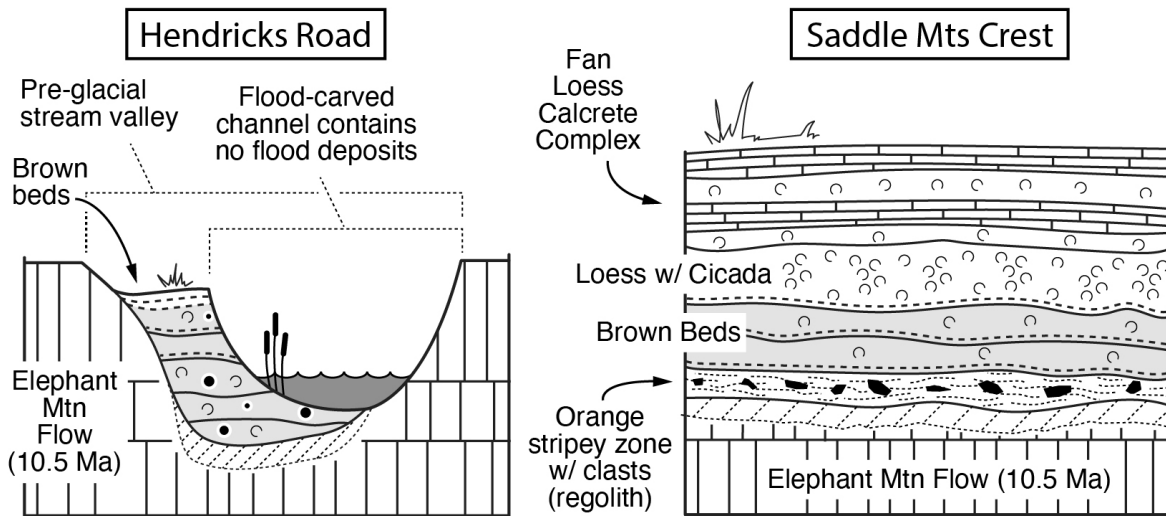
47.1600, -119.9015

Directions to White Trail/Rd 5 NW - From Quincy, drive S on Hwy 281 for 5 miles. Turn R (west) onto White Trail/Rd 5 NW at friendly Colockum Golf Course. Cross the canal at the Quincy Chute Hydroelectric Plant and promptly pull off into one of the orchard driveways on the N side of the road. The low roadcut is located on the south side ~200 m west of the canal at a power pole (#WAN-COL-AL-53-100603). Do not obstruct orchard operations. Truck traffic along White Trail is relentless.



Description - The White Trail site is located in western Quincy Basin at the head of Potholes Coulee cataract. A flood-cut, gravel-filled channel is incised into beds of brown, cemented alluvium identical to those at Hendricks Rd and Saddle Mountains. The beds are themselves incised into Priest Rapids ($M_{V_{wpr}}$) basalt. They contain faint cicada burrows and curious pebbles and chips of dark red opal. Bedrock dips gently west toward Potholes Coulee. A thick, flat-lying Stage III calcrete - thicker than at Hendricks Rd - caps both the pre-Wisconsin gravel and the brown Pliocene beds. The armoring calcrete traces SE to George and NE to Winchester.

White Trail. Gravel-filled channel and brown alluvial beds into which it is incised are both blanketed by calcrete.



White Trail connections. Distant exposures at Hendricks Rd near Connell and along the Saddle Mtn crest above Jericho contain nearly identical beds of pre-glacial brown alluvium.

Red Tank Hike from Upper Corfu Rd (Smyrna Bench)

Hike on north flank of Saddle Mts to cemented fanglomerate and deformed Ringold lakebeds

46.8120, -119.4656

Directions - This stop involves a 2-mile hike (roundtrip) which begins at the end of bumpy drive just north of the crest of the Saddle Mountains. Access to the informal trailhead is via a rough gravel road. From Othello, drive Hwy 26 west for 17.5 miles to the White Bluffs Area gate. Do not turn. Instead, continue west on the highway 2.8 miles farther. Turn R (north) onto the gravel road (Corfu Rd) signed "Saddle Mountains Overlook 5 miles". From Vantage, drive 19 miles to Mattawa, then follow Rd 24 SW (becomes Hwy 24) west for 20 miles and turn R (north) onto gravel road (Corfu Rd) signed "Saddle Mountains Overlook 5 miles". The mostly unmaintained gravel track ascends the south flank of Saddle Mountains, crossing the canal at 4.9 miles, after which potholes and washboard increase. At 7.1 miles reach the saddle crest and 4-way intersection (565 m elevation). Turn left and follow the curving road west, staying right at the branch, and downhill for 0.8 miles to the red metal tank. The road is rocky north of the intersection, so go slow. Higher clearance vehicles only beyond the intersection. Park off the road to the left in sparse sagebrush on a somewhat flat spot just past the red tank. Do not block Corfu Rd.

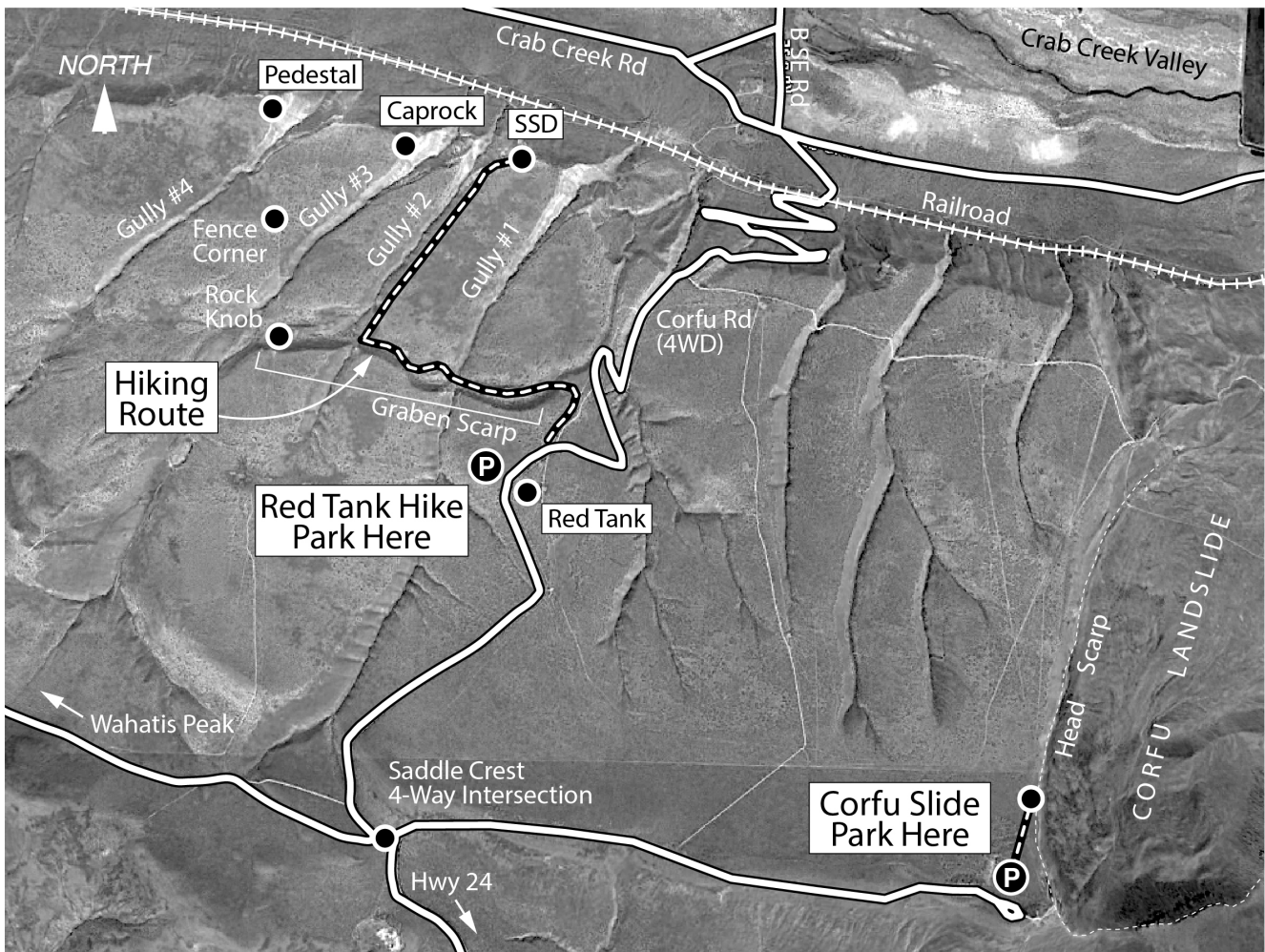
Hiking Route - Hike north for 1/4 mile downhill to join a worn trail leading west along fault scarps and through the "summit graben" toward a conspicuous knob of basalt. Just past the rock knob. A wire fence leads due north. Follow it to the fence corner, then farther north to SSD Outcrop located at the rim of Smyrna Bench. GPS waypoints shown below. One-way hiking distance is about 1 mile over easy-moderate ground.

The red tank is a reminder of an active period of oil and gas prospecting in Columbia Basin detailed in McFarland (1979), Campbell and Banning (1985), Brownfield (2008), Wilson et al. (2008), Tincher and Reidel (2009), and Czajkowski et al. (2012). Sedimentary interbeds between basalt flow were targeted.

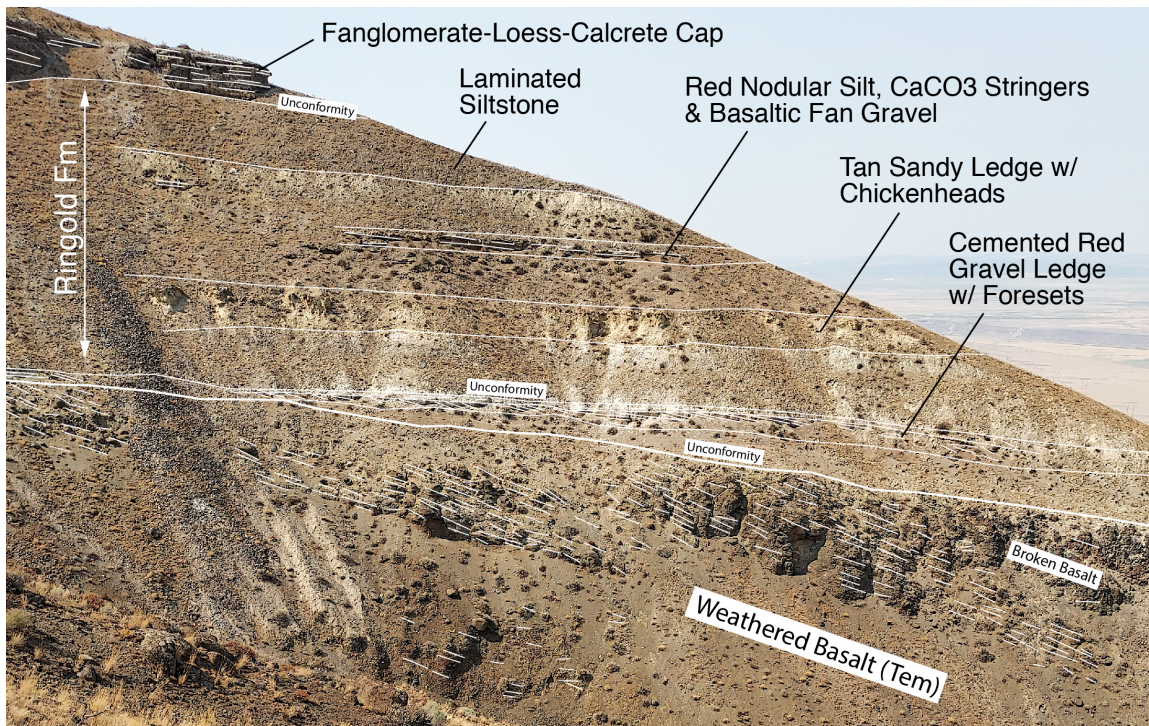
GPS Locations Along Hiking Route

Saddle Crest 4-way Int	46.7933, -119.4705	565m elevation	Along Corfu Rd
Red Tank	46.8024, -119.4653	480m elevation	Along Corfu Rd
Rock Knob	46.8069, -119.4746	412m elevation	Scarp/Gully #2-#3
Fence Corner	46.8099, -119.4758	400m elevation	Between Gully #3-#4
SSD Outcrop	46.8120, -119.4656	350m elevation	Gully #2
Caprock Outcrop	46.8126, -119.4701	370m elevation	Gully #3
Pedestal Outcrop	46.8132, -119.4762	36 elevation	Gully #4

Description - Impressive alluvial fan gravels (“fanglomerate”) of angular, locally-derived basaltic material more than 3m thick are heavily cemented with CaCO₃. Fan overlies tan, sandy beds of the Savage Island Member (upper Ringold Fm). The erosional contact between fan gravel and lakebeds has several meters of relief. The silty sandy beds have characteristics of both lacustrine and fluvial deposition (river-lake environment) and number more than a dozen. Soft sediment deformation (swirled bedding, loading features, pseudonodules) occurs repeatedly in the Pliocene beds, but the deformation is contained within the river-lake package and entirely predates deposition of the fan gravels. Older, flat-lying Bk horizons are truncated by the chaotic fan gravel. Each deformed bed is truncated and overlain by flat-lying deposits indicating pulses of deformation with resumption of lake sedimentation between. Overloading of wet, valley bottom sediments by rapid deposition of coarse fan material shed from the ridge is not the cause of the deformation. Pulses of finer grained material (fan toe?) flowing farther out on the valley floor appears to be. Deformation is syn-sedimentary, but not clearly syn-tectonic. They may be run of the mill flash flood deposits. The overlying fan gravel can be similarly interpreted. Its clearly a product of an actively rising ridge, but it isn’t necessarily an event deposit, an earthquake-triggered debris flow (seismite).



Red Tank Hiking Map. Map of route to SSD Outcrop and other outcrops on the Smyrna Bench near Corfu Road. The Corfu Landslide overlook is just to the east and a 4WD route leads west to Wahatis Peak summit towers. Corfu Rd from Crab Creek Valley is really rough and sandy. Best approach is from the south via Hwy 24.



SSD Outcrop. Smyrna Bench is capped by cemented basaltic fan gravels (fanglomerate) spilled from the rising Saddle Mountains ridge above. Fan gravels truncate deformed and cemented beds of the Ringold's Savage Island member (river-lake deposits). Repeated soft sediment deformation in the tan silty-sandy beds occurred prior to being overridden by the fanglomerate. Similar deformation at this same stratigraphic position occurs at numerous locations in the area.

Corfu Landslide Overlook & Calcrete Crust on Pomona Flow

Calcrete-silcrete crust on basalt at crest of Saddle Mountains anticline and a really big landslide

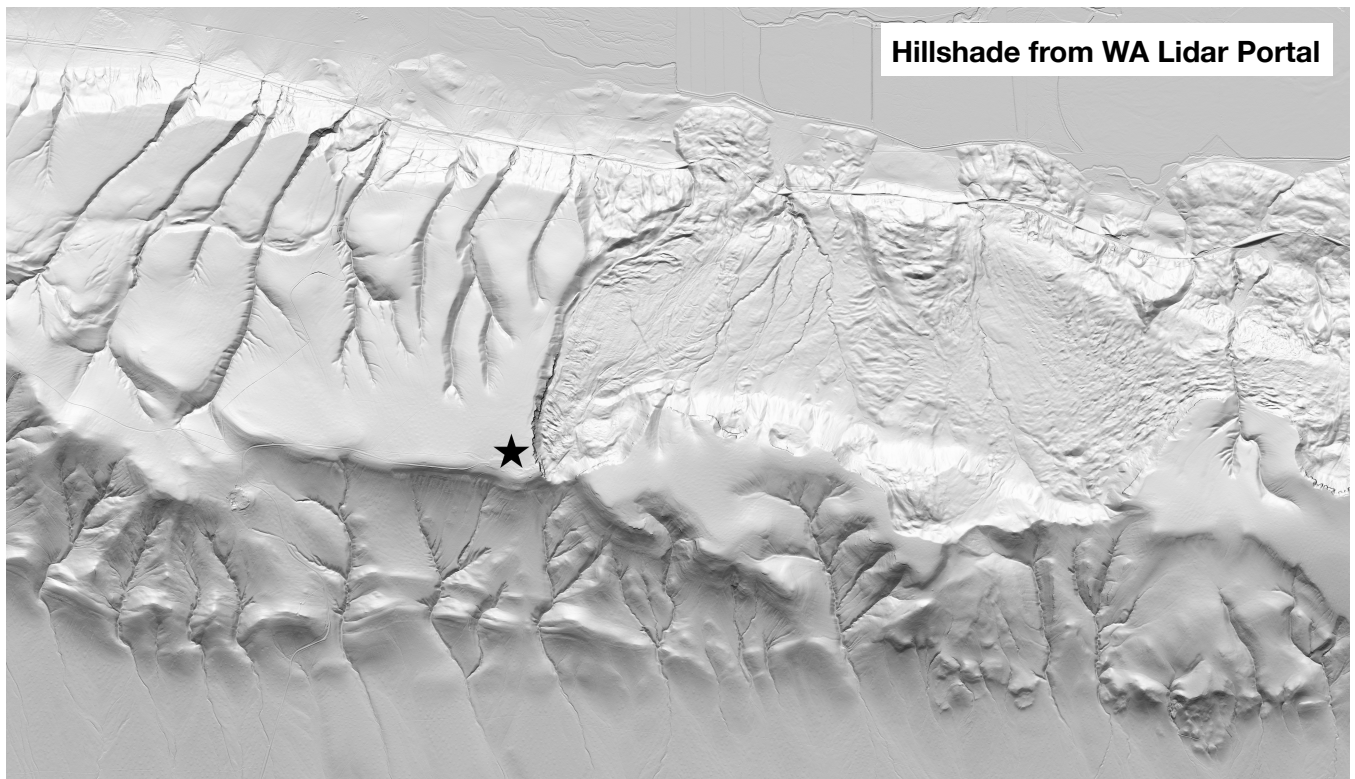
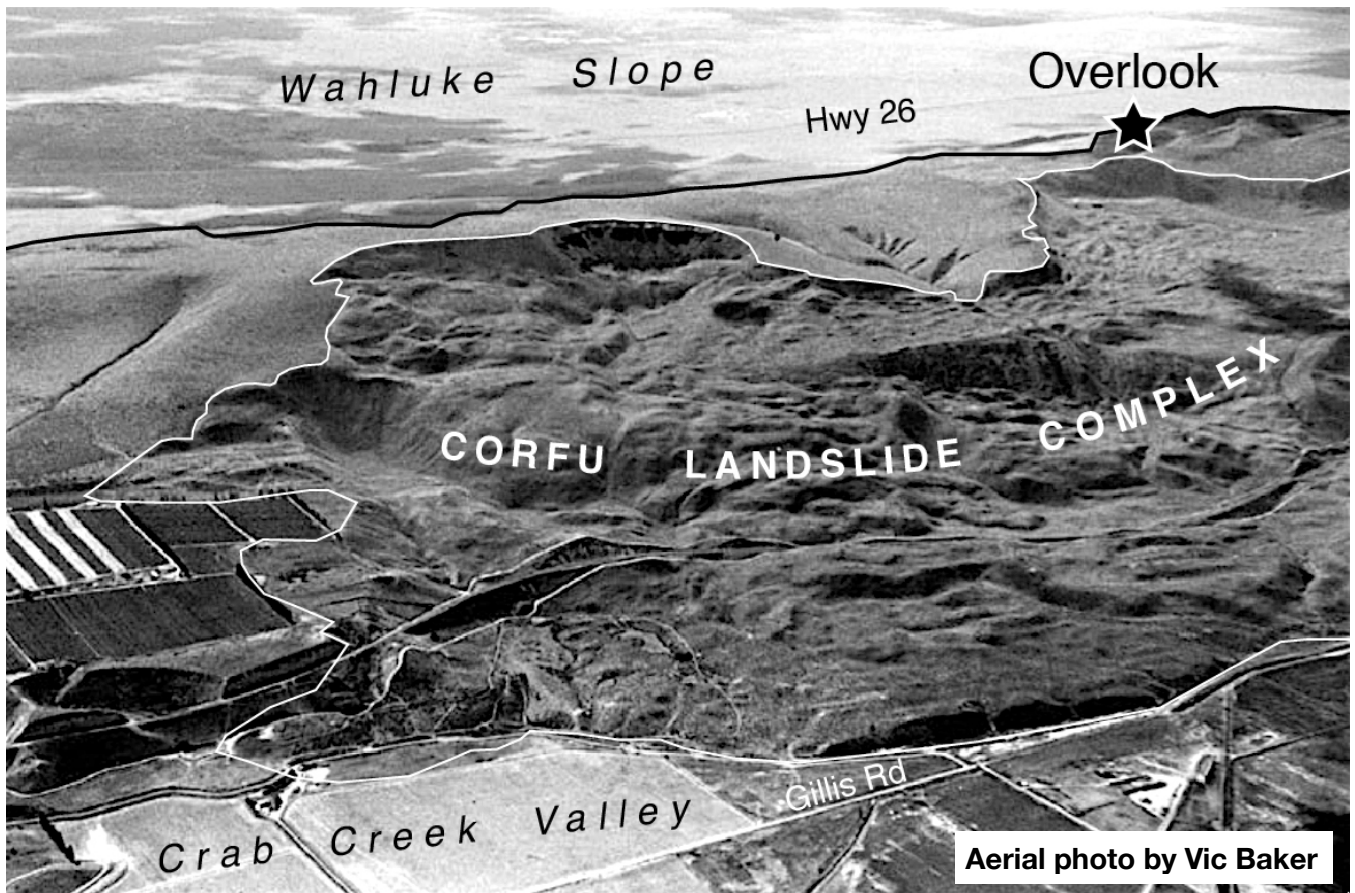
46.7919, -119.4461

Directions - Follow same directions as Red Tank Hike to 4-way intersection at top of Corfu Rd. Its a 20 mile drive east from Mattawa and about a 20 mile drive west from Othello on Hwy 24 to Corfu Rd turnoff from Mattawa. At the top of Corfu Rd (7.1 miles from Hwy 24), turn R (east) following the sign "Saddle Mts Overlook 1 Mile". Continue up the easy gravel incline to concrete slabs and road's end. Park and walk the short distance to the head scarp of the Corfu Landslide Complex (Lewis 1985, Baker et al. 2016). Calcrete-silcrete crust is exposed below, a short ramble down the cliff edge.

Description - The 10-40cm thick crust is developed into the cracked and weathered Pomona Member of the Saddle Mountain Basalt (12 Ma). Parent material is unclear. It is certainly fine grained, but all grains have been completely consumed. Little in the way of soil features. Appears to be a groundwater precipitate atop impermeable basalt. The unit formed when the basalt was flat-lying or nearly so, but today thins toward the crest of the fold. The crust is either the basal portion of the Ringold Fm or part of a thin, unnamed sedimentary interbed deposited atop the Pomona flow prior to uplift of the anticline. Either way, it highlights an erosional surface.



Corfu Landslide Overlook. A bright white calcrete-silcrete crust is exposed along the rim below the overlook. Calcrete-silcrete overprints an erosional surface atop weathered Pomona basalt. The same platy crust is found atop Elephant Mtn flow >25km to the west.



Booker Road at Canal

Loess and calcrete interfinger at transition from Palouse Slope to Channeled Scabland

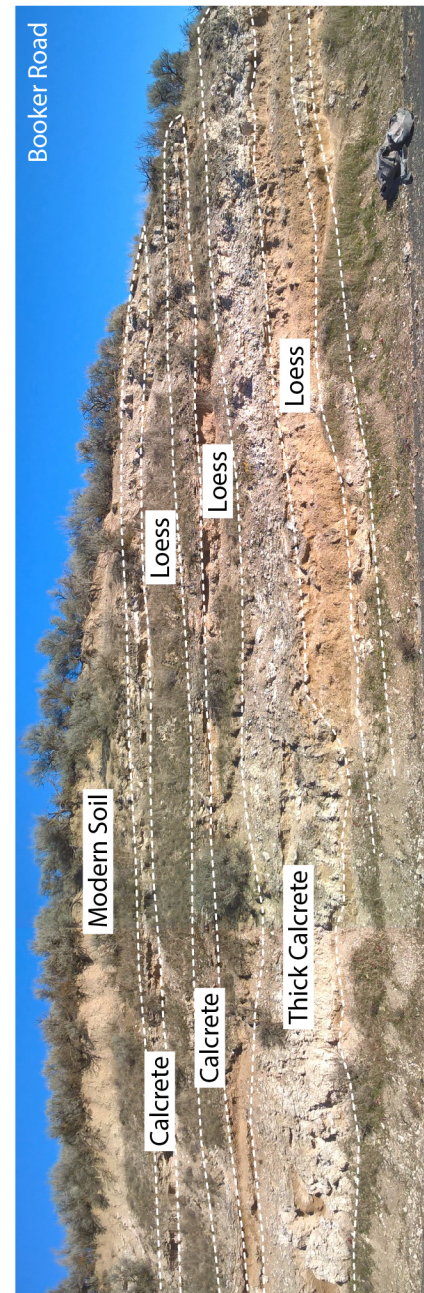
48.7827, -119.0483 ← Park vehicle

Directions - From Othello, drive east on Hwy 26 and turn R (south) on Booker Rd. Follow Booker Rd south for 1.3 miles. Pull off in on a farm driveway on W side at GPS location. Walk a short distance S to irrigation structure. Assemble group on the bluff overlooking the west-facing roadcut. Afternoon light is best. Truck traffic moves fast here. No roadside walking. If roadcut viewing isn't sufficient, cross Booker Rd and hike east along the canal escarpment to better outcrops in a few hundred meters.

Description - Interfingering Palouse loess and calcrete highlights the transition between two geomorphic domains: Palouse hills and Channeled Scabland. Paradise Flats, the broad plain that extends west from here to Othello, was swept and beveled by Ice Age floods. Basaltic sand mixed with calcrete rip-up gravels and chunks of Ringold Fm lie beneath many agricultural fields. Very large, rounded basalt boulders are found along Hwy 17 and on benches to the west.

Many Pacific Northwest geologists are first introduced to 'caliche' on field trips to the Palouse and thereafter equate caliche with Palouse soils. Caliche in Palouse soils, however, is often rather weakly developed (< Stage III), laterally discontinuous, and unquestionably formed by soil processes on upland hillslopes. High windblown sedimentation rates never permitted calcrete ledges to grow very thick. And upland soil profiles are removed a significant distance from the water table. Meter-thick, multi-story calcretes are actually better developed west of the Palouse in the lower, drier Pasco Basin where Othello is located. Pasco Basin calcretes are as old or older than the loess hills; some clearly pre-date the oldest loess (1.15 Ma, King et al. 2016).

The blocky, meter-thick calcrete ledge exposed near the base of the roadcut is typical of those in the Othello area (northern Pasco Basin). It has both pedogenic and groundwater characteristics. Here the ledge is overlain by a number of loess beds and thinner calcretes, the typical pattern in the Palouse Hills that extend to the east.



Watt Lane Landslide Scarp

Scramble on the scarp of an active landslide exposing Ringold Fm, paleosols, and flood gravels

46.5679, -119.2082

Directions - From Basin City, drive west on Rd 170. In a little over a mile turn L (south) onto Fairway Rd (Rd 170), which becomes W. Klamath Rd. As the road descends the slope west through ag land of lower Ringold Coulee, the landslide becomes visible in the bluff across the valley. At 4.5 miles, navigate a 4-way intersection, keeping right on Klamath Hill Rd, then turning quickly right onto Watt Ln. If you miss Watt Ln, continue to the top of the hill where there are safe places to turn around. Park near the end of Watt Ln, a dead end at the toe of the slide. Impromptu hiking trails lead through ever-changing slide debris and forest cover to the scarp. Google Earth may help locate the trail. The higher you go, the better the view of the exposed strata.

Description - Landslides in the area are caused either by Columbia River (toeslope erosion) or by agricultural irrigation (lubricated slide planes). This scarp is the latter type. Tens of meters of Pliocene Ringold strata truncated by coarse Pleistocene flood gravels are exposed. Pliocene strata is a mix of tan-green lake beds (Savage Island Member), red fluvial sandstones, oxidized nodular loess which resemble named Palouse paleosols, white ash beds, and a number of colorful paleosols. Cemented and uncemented layers interfinger. Several meters of boulder gravel containing abundant calcrete rip-ups unconformably overlie the Ringold. The section is undeformed except for a wavy, sagged zone in gray, crossbedded micaceous sand located at the top of the lake beds section, beneath a conspicuous orange paleosol. Flame structures, load casts, and a few small, descending, single-fill clastic dikes are found nearby. A contorted zone occurs throughout the study area in the same stratigraphic position. A short stack of grayish, slightly-tilted Touchet Beds containing a few sheeted clastic dikes is present at the base of the slide near the parking area. The Missoula floods slackwater rhythmites (< 20 ka) are inset into pre-Wisconsin age Ringold Coulee and partially overridden by slide debris.

Coarse megaflood gravels w/ calcrete rip-ups
Red, cemented, nodular loess
Green-gray wetland paleosol
Orange sandy paleosol and zone of soft sed deformation
Tan lakebeds w/ micaceous sands (Savage Island Mbr)

Watt Lane
Landslide
Scarp



Watt Lane Scarp. Pliocene Ringold, thick paleosols, and a coarse megaflood gravel at Watt Lane. The red-white-orange section is loess and paleosols at the Plio-Pleistocene transition. A deformed zone lower down occurs at the top of the Savage Island lakebeds.

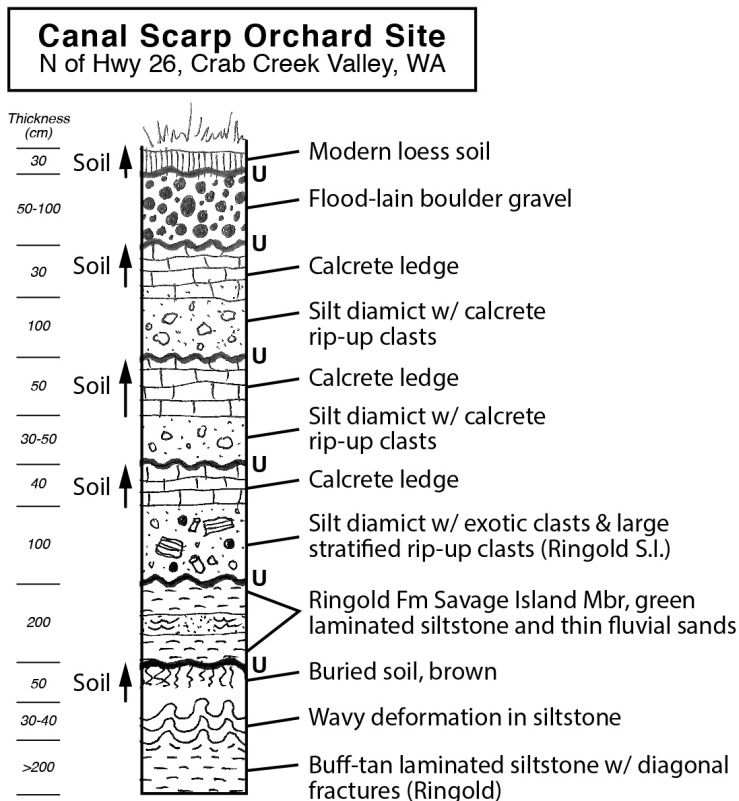
Taunton Bench Railway Ramble - Danielson Road to Hays Road

Hike Palouse-Cascades railway to flood-laid boulder gravels, Ringold, and calcrete-bearing sediments

46.8030, -119.3342 ← Parking pullout at sharp bend

Directions - From Othello, drive west on Hwy 26 into Crab Creek Valley. At 7.2 miles, turn L (south) onto Danielson Rd. Gain the slope and park in a pullout at the sharp bend near Taunton Heights Ln sign. Hike the abandoned railroad tracks (Palouse to Cascades State Park Trail) east to several slide scarps and railcuts that reveal interesting relationships between upper Ringold sediments and coarse megaflood deposits. Turn around after ~3 miles, when parallel with Hays Rd (46.8084, -119.2739).

Description - The half dozen or so outcrops (railcuts, slide scarps) can be examined on foot over the course of a few miles and a few hours. The contact between Ringold Fm and megaflood deposits is of particular interest for this off-the-beaten-path geology hike. Nothing simple here.



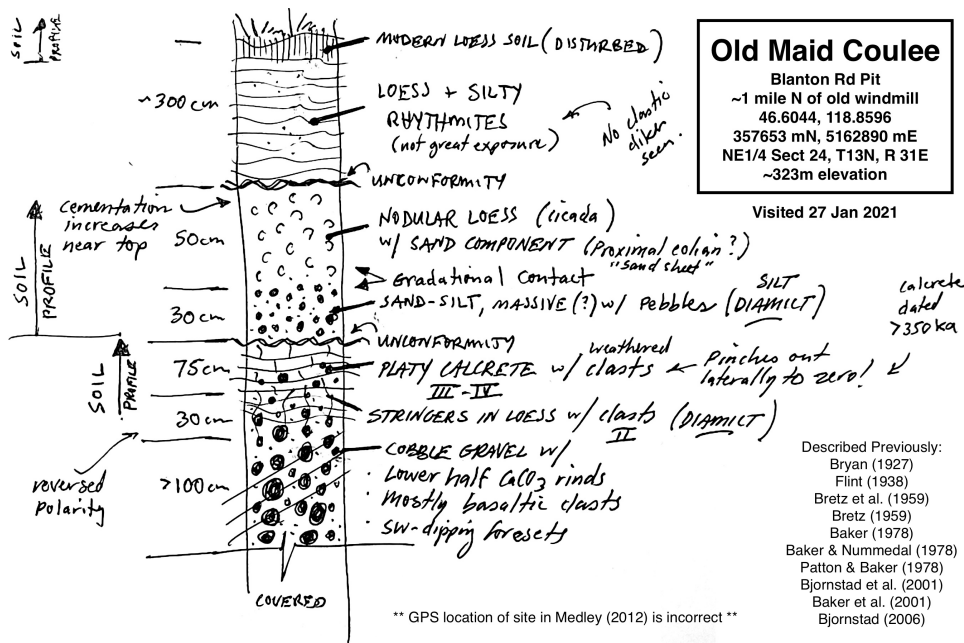
Old Maid Coulee at Blanton Road

A classic site containing calcrete, a pre-Wisconsin flood gravel, younger Touchet Beds, and loess

46.6045, -118.8595

Directions - From Connell, drive east on Hwy 260. Cross over Hwy 395 and turn R (south) onto Blanton Rd and continue south for 3.3 miles. The site is a humble borrow pit on west side of road. Park on the shoulder opposite the pit.

Description - Discovered early in the 20th century (Bryan 1927) and described by Bretz et al. (1956) and Baker (1973), Old Maid Coulee was recognized early on for its 'ancient' (pre-Wisconsin) scabland gravels. About 20 such sites are listed in Coppersmith et al. (2014, Appendix E, p. 4.11).



Old Maid Coulee.

Easily accessible pit along Blanton Rd provides a good look at a long and diverse record of sedimentation, including an ancient flood gravel cemented by calcrete overlain by a silt-pebble diamict, cicada-burrowed loess, and Touchet Bed rhythmites.

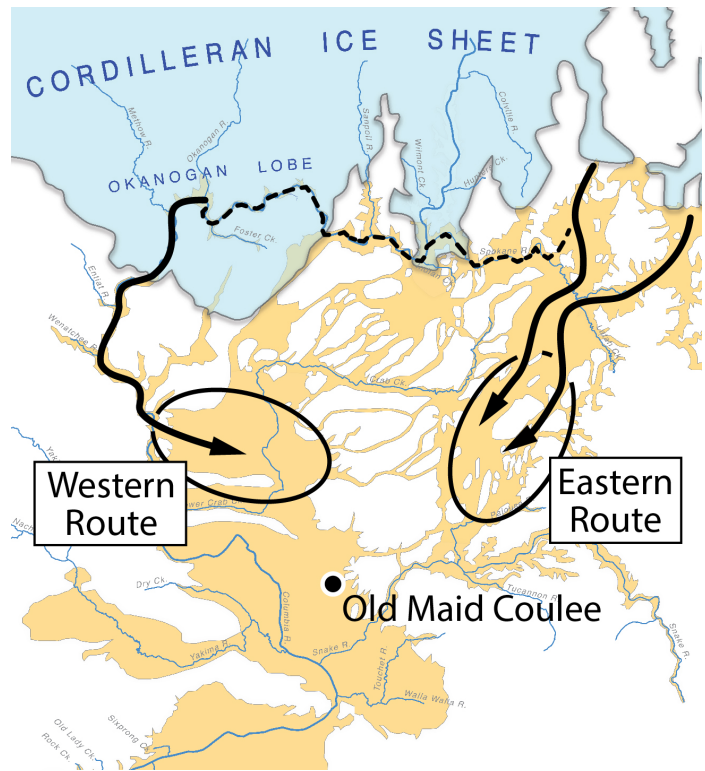
A cobble gravel at the base of the exposure exhibits south-dipping foresets and a reversed magnetic signature (>780 ka, Bjornstad et al. 2001). The gravel is capped by an advanced-stage calcrete that dates to at least 350 ka. Pebbly silt diamict (clasts floating in silt matrix) unconformably overlies the calcrete and grades upward into modestly CaCO₃-cemented 'L2' nodular loess. The nodular texture is the product of thousands of backfilled feeding burrows of cicada nymphs. Touchet Beds - thin, silty, uncemented flood rhythmites - lie above, deposited during slackwater phases of late Wisconsin Missoula floods (18-14 ka).

The routing of an early flood to Old Maid Coulee is curious. Pre-Wisconsin floods were few in number, judging by what's preserved - fewer than five and perhaps just two really large ones. Pockets of ancient gravel capped by calcrete cluster on the opposite sides of the Scablands. A single floodpath cannot explain gravels in both the western Quincy Basin and the eastern Cheney-Palouse tract if our understanding of gravity and an ice-blocked Columbia is correct. A 'western route' appears to follow an ice-free Columbia River corridor from somewhere upstream of Pateros > Wenatchee > Quincy Basin >

Drumheller Channels > Pasco Basin. An ‘eastern route’ appears to be Cheney > Benge-Harder-Marengo area > Lind and Washtucna Coulees > Esquatzel Coulee > Pasco Basin. Both eastern and western floods appear to have converged at the long-lived structural low at Othello (Drumheller Channels and Othello Channels/Eagle Lakes scabland) before heading through Pasco Basin to Wallula Gap.

Some geologists are skeptical of a so-called ‘ancient’ flood record. They remain unconvinced that cemented gravels like the one at Old Maid Coulee and two dozen other sites are actually flood-laid. Detractors attribute the coated exotic clasts, silt diamicts, deep chroma loess, paleosols, sediment-filled coulees, reverse-polarity signatures, and lithified clastic dikes to more mundane alluvial processes of local streams. Its alluvium, nothing more. While a certain amount skepticism is legitimate, J Harlan Bretz presented evidence for large, old floods more than a century ago and new sites are still occasionally discovered (i.e., Herman Railcut). The ancient flood record can be rather subtle and patchy, what Spencer and Jaffee (2002) call the “indirect record”. Pre-Wisconsin deposits are often thinner, lack familiar characteristics of younger deposits (i.e., silt diamict), and appear far less bombastic than deposits left behind by the Missoula floods.

Contrary to current understanding, Bretz believed the older flood set, his ‘Spokane floods’ (>125 ka), were much larger and more erosive than the younger Missoula floods (< 20 ka). By about 1978, the opinion had shifted in favor of the younger flood cycle. The shift away from Bretz can be attributed, in part, to absolute age data and surface exposure dates on flood-deposited and ice-rafted boulders, but also to dated tephra from Mount St. Helens and Glacier Peak, and clear cross cutting relationships seen in the field. But Bretz was no dummy. Most of his field observations and well-reasoned interpretations have stood the test of time, earning him the benefit of our doubt. There is an ancient flood record out there, as Bretz said. We can quibble over its age and other details as we must, but no question its there. In places, quite subtle, in others colossal, monstrous, stupendous (i.e., high elevation gravels in the Clark Fork Valley noted by Joseph Pardee in the 1940s, described by Larry Smith 80 years later). The post-Bretz ideas, now aged some 40 years, may yet find themselves under revision as discoveries at the Scabland’s fringes find their way to publication.



Pioneering flood routes? Calcrete-capped flood gravels occur in eastern and western portions of the Channeled Scablands. A single floodpath cannot explain gravel occurrence in both places if our understanding of an ice-blocked Columbia is correct. Ancient floods appear to have converged on Othello, a structural-topographic low spot since at least the Pliocene. Some floodwater remained in the Columbia channel, but some portion may have taken a short cut to Wallula Gap.

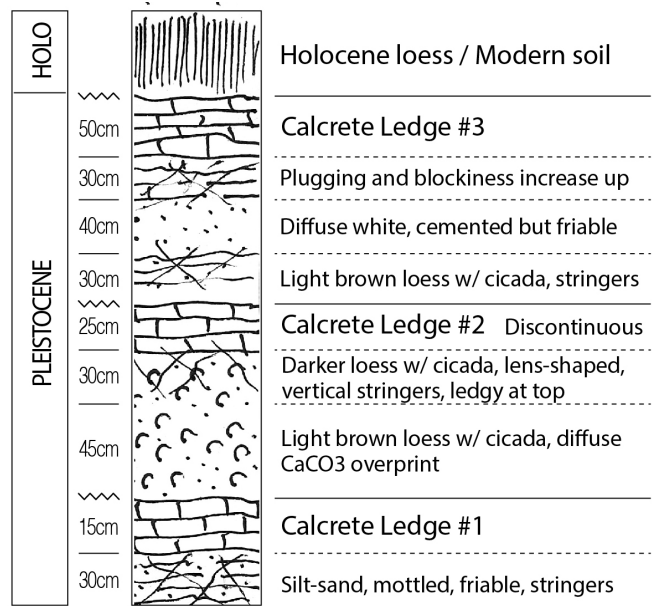
Pacific Road at Ritzville

Thick calcrete overprints loess on the western Palouse Slope

46.1308, -118.3722

Directions - The outcrop is an old excavation in a vacant neighborhood lot at the corner of 1st Street (Danekas Rd) and Pacific Street in Ritzville about 1/2 mile south of the Top Hat Motel. Park on the street or in the vacant lot. A large group will be conspicuous.

Description - Pacific Rd is located in a scabland coulee crossing Palouse hills. Strata exposed here is repeated loess and calcrete similar to exposures at Booker Rd east of Othello and Lind Rd east of Connell. Calcrete grows thick low in the landscape. Sediments at Pacific Rd are those of a low, pre-glacial stream valley widened by Scabland flooding and partially filled with loess crusted with calcrete.



Pacific Street at Ritzville. Stacked calcretes and cicada-burrowed loess at Ritzville. The site is located on the Palouse Slope in a low-elevation scabland coulee near the eastern margin of the Ringold lake basin.

Marengo Railcut

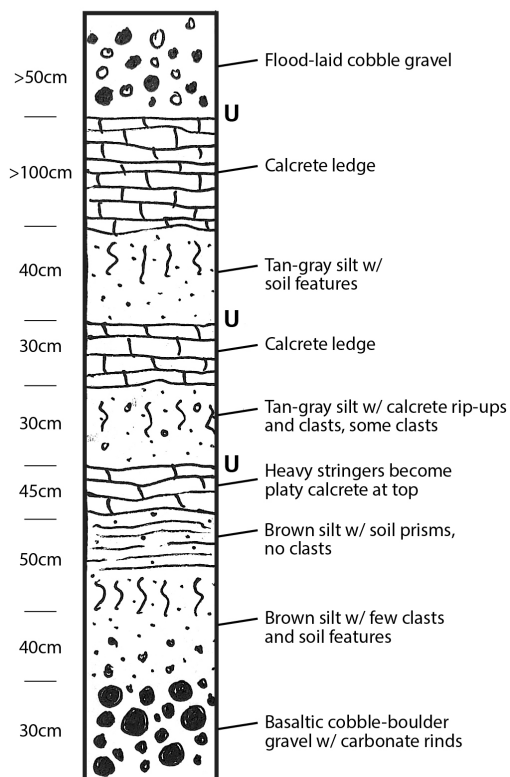
Ancient flood deposits and loess interfinger in a transitional region between Scablands and Palouse

47.0122, -118.2140

Directions - From Ritzville, drive 5.2 miles east on Wellsandt Rd, turn R (south) on Hills Rd and follow for 4 miles. Turn L (east) on Urquart Rd for 1.4 miles. Turn R on Marengo Rd for 3.7 miles. Cross the tracks at the Marengo grain elevators, bearing right on Cow Creek Rd. Follow for 0.8 miles to another crossing. Park here on the wide shoulder (shorter walk) or back at the Marengo elevators (longer walk). Follow old railway to a double-sided cut at a sweeping bend slightly elevated above the Cheney-Palouse Scabland Tract (Cow Creek Valley). The railway is the 'Palouse to Cascades State Park Trail', formerly the Old Milwaukee Road.

Description - Marengo is a classic site set among streamlined islands of Palouse loess. Calcrete ledges, two flood gravels (one old, one young), and several loess beds with a variety of soil features are on display. Some of what appears to be loess actually contains pebbles and small cobbles suggesting it has been reworked by flowing water (silt-pebble diamict). Nick Zentner and Skye Cooley filmed their visit to the site in July 2023 (Nick Zentner's YouTube channel: 'Pre-Missoula Ice Age Loess w/ Skye Cooley').

Marengo Railcut
North of Washtucna, WA



Flood-loess-calcrete cycles.

At Marengo, water, wind, and soil processes were dominant at different times in the past. The pattern is consistent with its position in thick loess region, but at the margin of a major scabland channel a portion of which is Cow Creek Valley.

East Trinidad at Baird Springs Road

Calcretes overprint hillslope colluvium, loess, and flood gravel(?) atop corestones of basalt

Directions - From Wenatchee, drive 25 miles east on Hwy 28 to Trinidad. Turn L (north) onto Baird Springs Road NW and follow for 0.8 miles. Park on shoulder, cross tracks, and hike a dirt two-track uphill the short distance north to the white outcrop, an old roadcut.

47.2425, -119.9933

Description - Located at the western edge of Quincy Basin, western limit of calcrete distribution, and western margin of Pliocene basin fill (i.e., Cheney 2016), the section contains sediments and calcretes developed in Palouse-like loess and scabland-like gravels, a pattern echoed at several other stops in this guide.

Two modest calcretes are separated by wedges of loess and brown silty-sandy-gravelly beds. Though not a thick or visually stunning exposure, the site's position between more formidable and convincing exposures - calcrete-capped gravels at Fancher Bar and George - is important; East Trinidad provides a fortuitous point of continuity for the blanket-like calcretes.

The lower calcrete is 30-50cm thick with platy to blocky morphology that becomes fully plugged in its upper 15cm, as is common of ledges in the region. The upper calcrete is less advanced, 25cm thick, with blocky to platy morphology. Both calcretes are developed into silt-sand-gravel parent materials (alluvium) containing trace fossils of plants. Thick colluvium atop the bedrock contains rip-ups of green mudstone and basalt in a powdery matrix. White cement fills cracks in the top of the basalt bedrock below. Boulder-like corestones of basalt weather nearby.

Contacts between the various sedimentary beds reflect both surface instability (colluvium, lens-shaped beds, angular relationships) and surface stability (calcareous soil profiles, root casts, burrows). Bedding follows the angle of the hillslope, which is curious. Are the sediments (parent materials for calcretes) slope or valley deposits, colluvium or alluvium? Is bedding tilted by recent uplift of Badger Mtn anticline? What evidence is there for block-slide mass wasting, which also might explain the tilt?