River Geology and Rafting

A Portfolio
By

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For

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ES 508
Western Oregon University
Summer 2009

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Introduction *

This field trip focused on the geology, geomorphology and hydrology of selected areas of Oregon. In other words, we were exposed to information about formation and deposition of bedrock, how that bedrock has been acted upon over time by the earth processes of tectonics, climate induced phenomena such as glaciers and rivers and other geologic processes such as volcanism and finally, how all of these processes and the existing features interact in the present time.

Our itinerary started in east-central portion of the Willamette Valley at Western Oregon University in Monmouth, Oregon, continued eastward across the Oregon Cascades, and onto the western edge of the High Lava Plains. We explored Newberry Crater and other faulting and eruptive features of the High Lava Plains and then headed North to the Deschutes-Columbia Plateau and the Columbia Gorge where we investigated Columbia River Basalts and features of the Missoula Floods. From there we headed back south to the Deschutes River at Trout Creek, traveled north by raft and studied the geology, geomorphology and hydrology of the Deschutes River.

In general, we find that the geologic history of our entire region, meaning the Pacific Northwest in general, and Oregon specifically, is marked by continuous, very active plate tectonics resulting in uplift, faulting and repeated volcanic flooding with basalts punctuated by repeated violent eruptions of stratovolcanos and deposition of volcanic material in general. Earthquakes and large landslides are common. The region is carved by glaciation. Its rivers are frequently flooded by meteorological events as well as by geologically formed dams that fail in spectacular fashion. It is not a boring place for earth scientists!

Geologic Timelines

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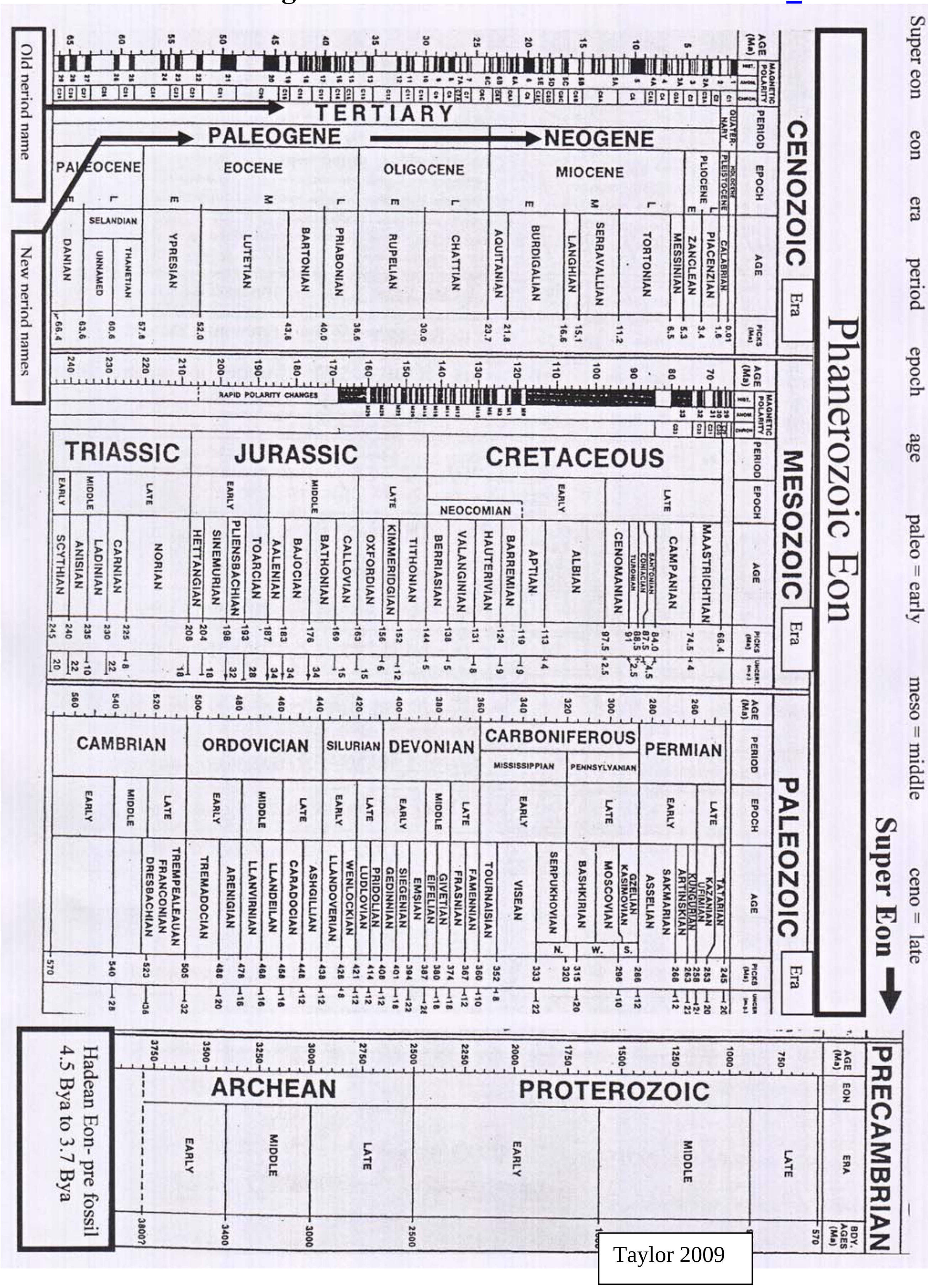
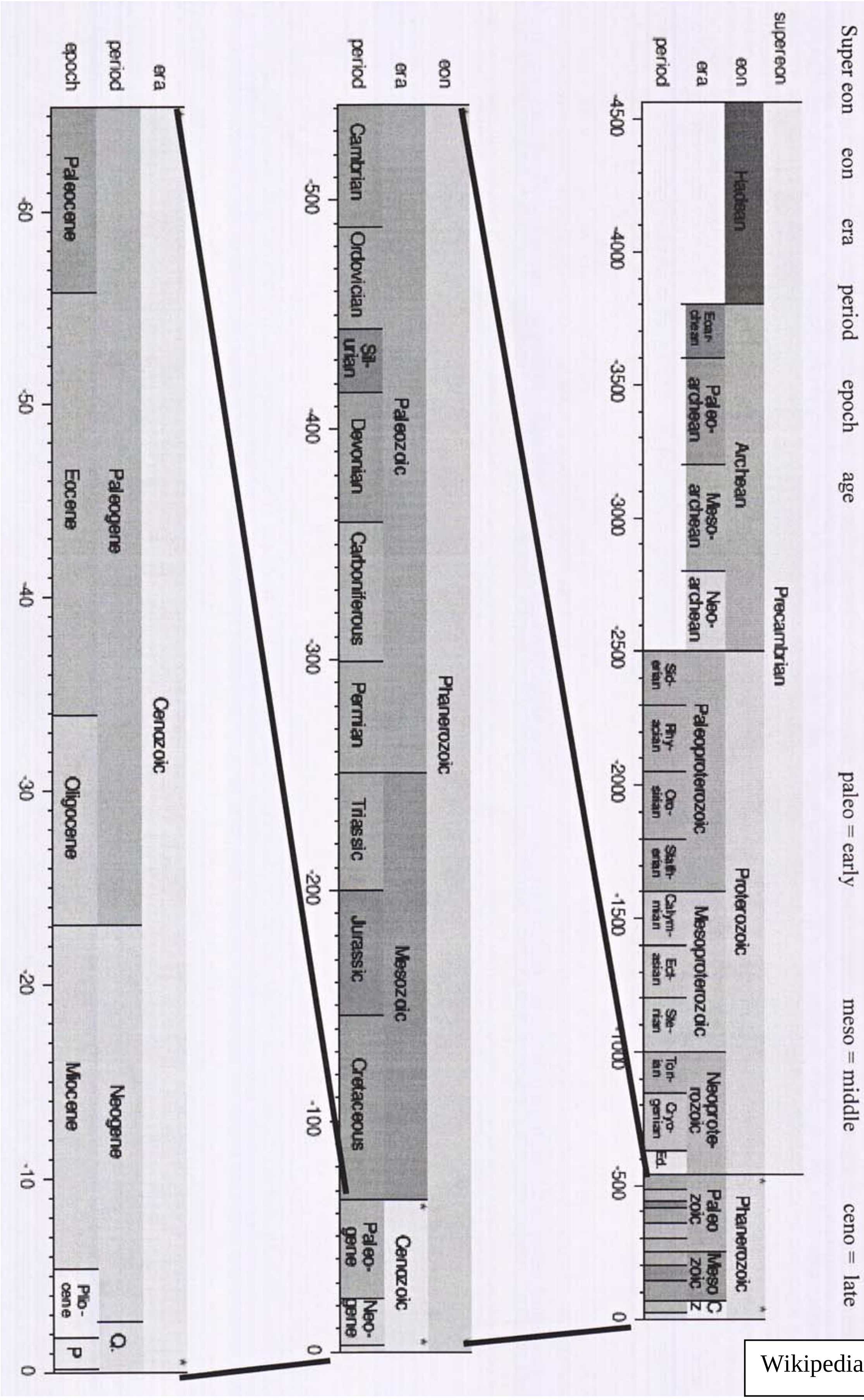
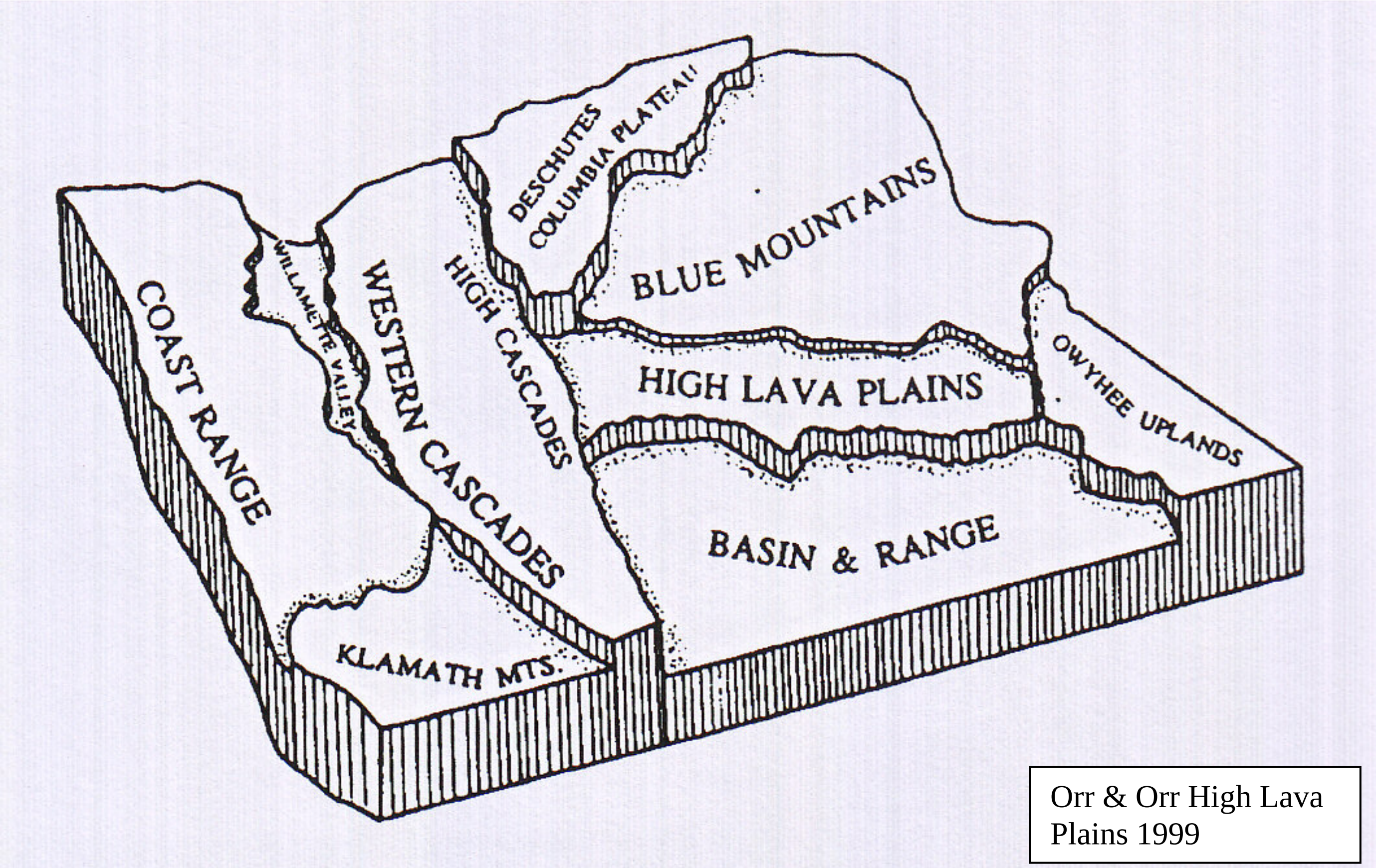




Wikipedia 2009



Orr & Orr High Lava Plains 1999

PROVINCES OF OREGON *

- Orr and Orr (1999) - State Physiography, Blue Mtns, Klamath Mtns, Basin and Range

Bedrock Formation Ages (Ma) *

Formation	Age					
Yonna Formation of former usage	(2-7 Ma)					Ts_1
Troutdale Formation	(2-7 Ma)					Ts_1
Deschutes Formation	(2-7 Ma)	Tb_1		Td_1		Ts_1
Sandy River Formation	(2-7 Ma)					Ts_1
Dalles Formation	(7-17 Ma)		Ta_2			Ts_2
Rhododendron Formation	(7-17 Ma)		Ta_2			
Sardine Formation	(7-17 Ma)	Tb_2	Ta_2			
Columbia River Basalt Group		Tcu	(6-13.5 Ma)			
		Tcl	(14.5-17 Ma)			
Breitenbush Tuff	(17-25 Ma)	Tb_3	Ta_3			
Colestin Formation	(25-35 Ma)	Tb_4		Td_4		Ts_4
Little Butte Volcanics	(17-25 Ma)	Tb_3	Ta_3	Td_3	Tr_3	Ts_3
	(35-45 Ma)	Tb_4	Ta_4	Td_4	Tr_4	Ts_4
John Day Formation	(17-25 Ma)				Tr_4	Ts_3
Eugene Formation	(35-45 Ma)					Ts_5
Fisher Formation	(35-45 Ma)	Tb_5	Ta_5			Ts_5
Spencer Formation	(35-45 Ma					Ts_5
Clarno Formation	(35-45 Ma)		Ta_5			

Notes and Summaries-Regional Geologic Setting of the High Lava Plains and Deschutes-Columbia Plateau *

Annotated outlines and written summary of pre-trip readings on 1. High Lava Plains 2. Geologic Overview of Newberry Volcano 3. Deschutes-Columbia Plateau

HIGH LAVA PLAINS- outline *

Physiography

- 50 x 150 miles long
- 5000 ft avg elev.
- Relatively smooth plain
- Elev from 4080 to 7984 ft at berry
- Cascades rainshadow
  - low rainfall
    - Poorly developed stream network-
    - Sparse vegetation
    - Easy to see geologic and geomorphological features

- Deschutes River
    - Western edge of HLP
- Malheur & Harney Lakes-
    - playas at times,
    - center of undrained basins to the east,
    - nearly dry

Geologic Overview

- Remarkable volcanic features,
    - Cones, buttes, lava flows and tubes throughout region
- all relatively young
- most rocks are volcanic
- 10 mya 1st eruptions
- 2 large underlying crustal blocks
  - opposite direction of movement
  - broad zone of faulting
  - numerous and continuous eruptions
  - numerous volcanoes and eruptive features hallmark of region
- Large Lakes present during Pleistocene ice age
  - Rec'd fluvial sediments and volcanic ash
  - Dried out to become playas (interior drainage, flat, mud to sand bottom) today

Geology

- 10 mya eruptions started in southeast and moved northwest along Brothers Fault System
  - Bothers Faults-result of the movement of underlying plates
    - Dominant feature of the high lava plains
    - 130 miles long from Steens Mountains to Bend
    - over 100 separate rhyolitic volcanic centers along Brothers
    - Many faults of this system are easily seen with aerial photographs
    - Crack in the ground, in Christmas Valley, especially obvious
- Newberry Crater
    - At Apex of Brothers (SE to NW)
        - Walker Rim (SW to NE)

Green Ridge/Sisters aka Tumelo (N to S)
Separate, younger, to the east of cascades
Recent eruptions rhyolitic
Indicate end of eruptive cycle

Bimodal Lavas
- Basaltic
  - Deeper source
  - Higher temp
  - Less silica
  - Less viscous
- Rhyolitic
  - Shallower
  - Later
  - Higher silica, more viscous
- Basalt dominates region
- Rhyolitic extrusions and domes punctuate the fracture zones
- Bimodal is rare
  - Only where crust is thin, such as in Central Oregon- stretching.

Northwestern movement of eruptions very striking
- Movement of plate over hotspot, like Yellowstone? Unlikely.
  - Age progression would be reversed from west to east because N.American plate is moving west.
- Most likely due to deepening of subduction zone below eastern Oregon
  - Eruptive front moved west as angle of subduction placed molten center farther west.

Pleistocene Lakes
- Up to approx 11,000 ya Great Basin had many large shallow lakes
- Most have become playas
- Prehistoric Fort Rock Lake (1400 mi^2) and Malheur Lake (900 mi^2) were largest
- Sediments provide record of animals, plants, man during ice age
- Environment more lush than now, higher density of mammals, plants
- During high water Pleistocene, many of the lakes were interconnected as one large lake
- Features such as Fort Rock, created when groundwater struck hot magma and exploded were islands.

Harney basin-
- formed by downwarping and major caldera system long since unrecognizable.
- Interior drainage (no outlet)

Interesting Features
- Hole in the ground
- Fort rock
- Four craters Devils Garden Squaw Ridge Lava Fields
- Diamond Craters
- Volcanic Buttes
  - Pilot Butte
  - Powell Buttes
  - Newberry Crater
    - Low profile, shield volcano
    - 40 mi N/S, 20 mi E/W
    - one of largest quaternary volcanoes in U.S.

- Caldera formed
- Short lived volcano, only about 500K yrs.
- Eruptions 300-400k ya
- Obsidian discharged 2k ya- source for Indians
- Mt. Mazama ash layer (6900 ya) present, helps date recent eruptions
- 3 directional sets of 400 parasitic volcanoes
  - ongoing study suggests alignment with three fault systems converging
- drained by Paulina Creek to Deschutes
- Geothermal interest hopefully will die down due to environmental concerns

Lava Butte
- Classic basalt cinder cone
- Flank of Newberry- parasitic
- Erupted about 6k ya, 8 events
  - Dammed and diverted Deschutes
    - Bentham Falls still exists
- Created Lava Cast Forest- encased and burned trees to create a "mold" cast
- Glass Butte
  - Source of obsidian for Native Americans

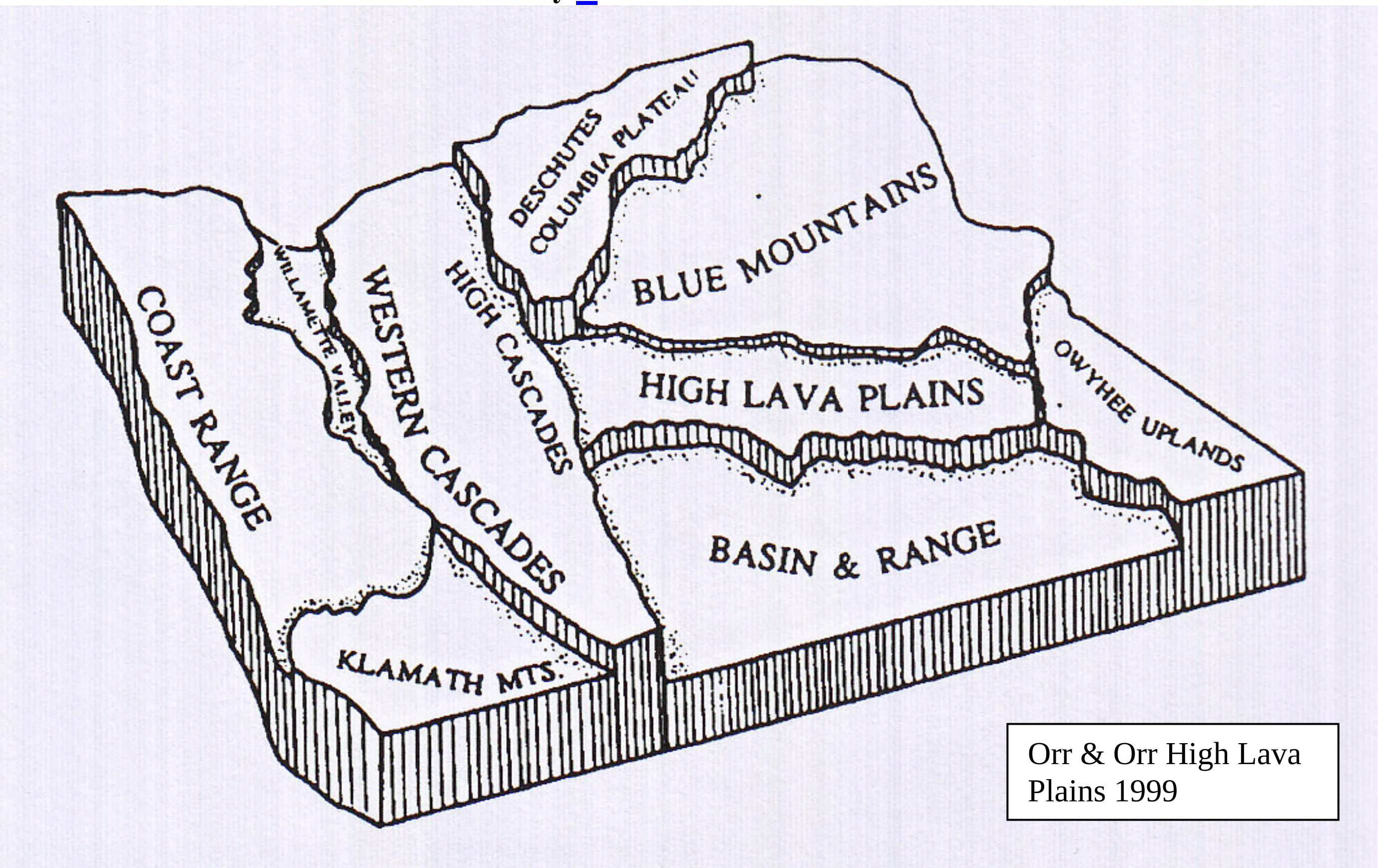
Lava Caves

Crack in the Ground
- In Christmas Valley, just S of Four Craters Lava Field
- Visible in aerial photos, very distinctive example of fault.

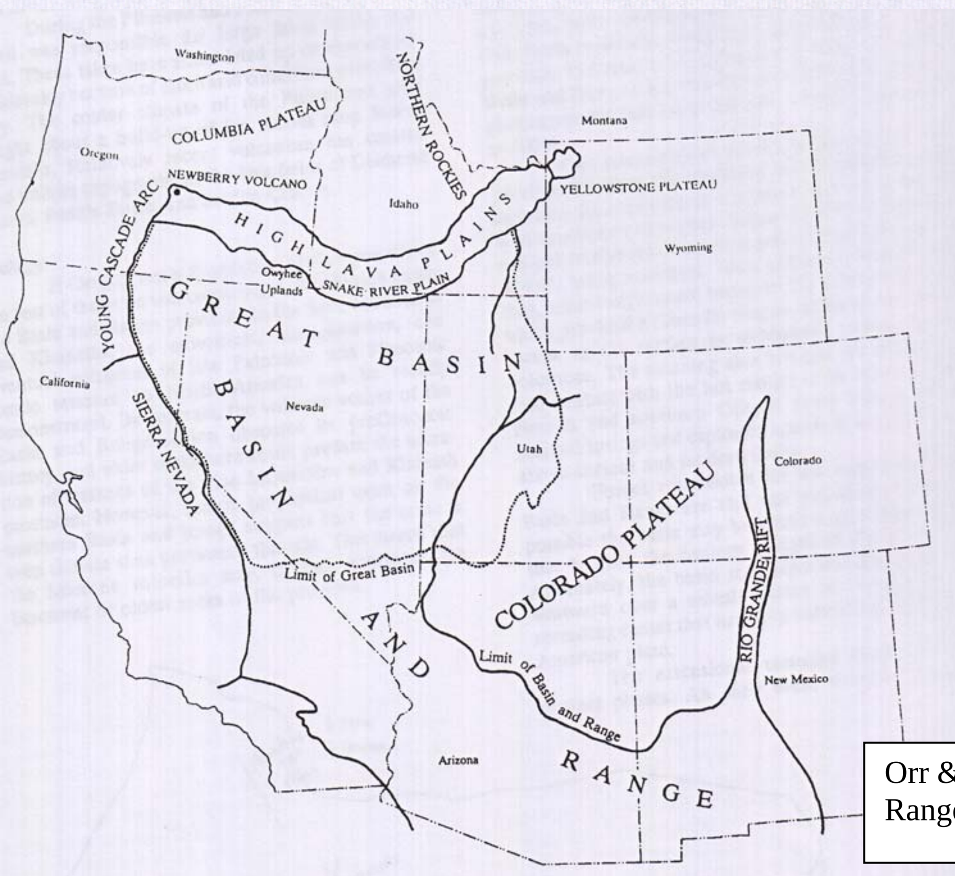
Smith Rock
- Volcanic tuff, eroded by Crooked River.

All notes derived from Orr & Orr Overview of High Lava Plains 1999

HIGH LAVA PLAINS- Summary *



Orr & Orr High Lava Plains 1999



The Great Basin portion of the Basin and Ran
province barely extends into southeast Orego

Orr & Orr Basin & Range, 1999

Physiography

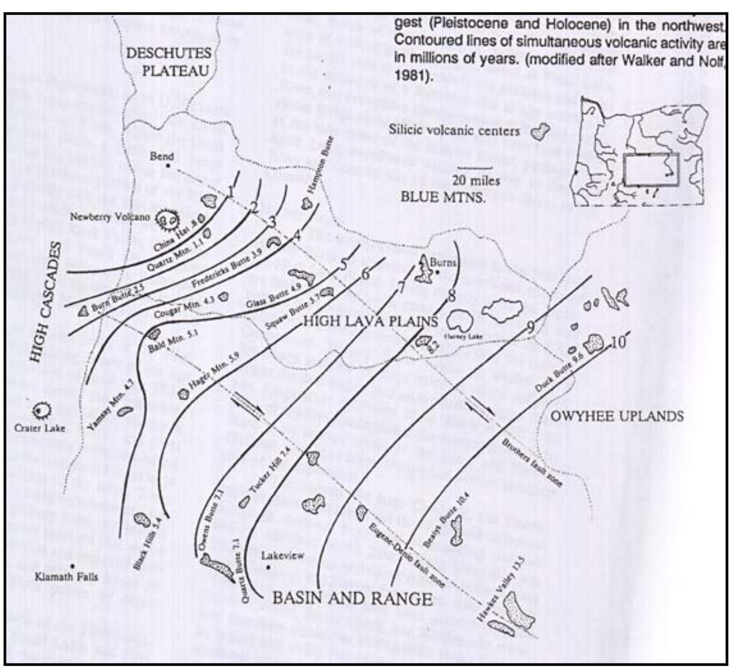
The High Lava Plains physiographic province runs roughly east west across central Oregon, from the High Cascades on the west to the Owyhee Uplands to the east. Some models show this province continuing and joining with the Snake River Plain, although the two have very different geologic origins. This province is a relatively smooth plain punctuated by numerous volcanic features. Its lowest point, in the Harney Basin is 4080 feet and its highest point is Newberry Crater, at 7984 feet. The High Lava Plains are subject to the Cascades rain shadow, which results in low rainfall, sparse vegetation and poorly developed stream networks. This makes it an ideal place to observe geomorphological features.

The Deschutes River is one distinctive feature partly contained by the High Lava Plains. Its sits at the western end of the province, just east of the High Cascades. It is much more developed than other stream systems because it benefits from ground water collected from the High Cascades, making it perhaps the least fluctuating river, and one of the most unique in the United States.

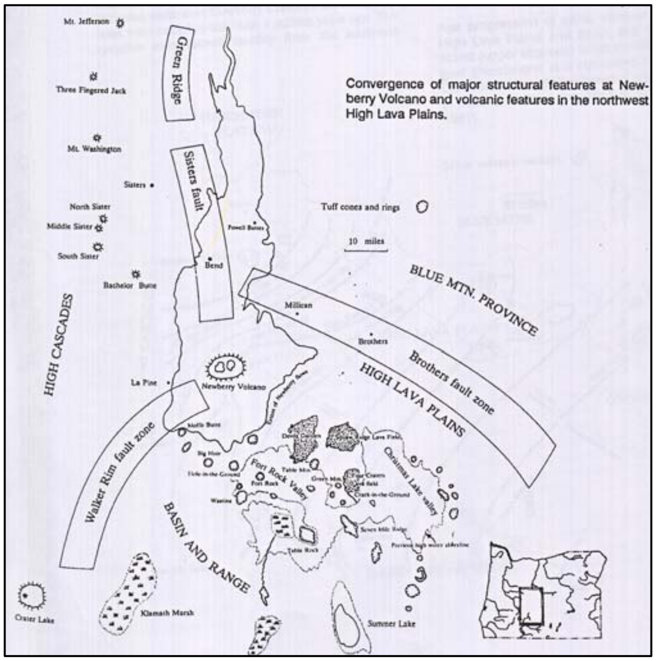
The eastern end of the High Lava Plains contains Malheur and Harney Lakes as well as other smaller lakes associated with the Malheur and Harney Basin. These are remnants of great pluvial lakes that existed during the Pleistocene Ice Age, and most are now playas. These two lakes are the center of undrained basins in the east of the province, and are nearly dry today, although they do overflow their boundaries and create shallow floods over much larger areas during exceptionally wet periods.

Geologic Overview

The HLP has remarkable and plentiful volcanic features- cones, buttes, lava flows and lava tubes- throughout the region. All of these are relatively young in geologic time. Most rocks are volcanic. The first eruptions occurred in the southeast section of the province, gradually and steadily moving northwest, with constant eruptions occurring for several million years. The location of such volcanic features is the result of broad zone faulting, which in turn is the result of the movement, in opposite directions, of two large, underlying, crustal blocks. The numerous and continuous eruptions, and the spread of these features throughout are a hallmark of this region.



gest (Pleistocene and Holocene) in the northwest. Contoured lines of simultaneous volcanic activity are in millions of years. (modified after Walker and Nolf, 1981).



As mentioned, large pluvial lakes were present during the Pleistocene Ice Age. These received fluvial sediments as well as volcanic ash from the many eruptive events. The spreading of the Basin and Range, of which the High Lava Plain could arguably be considered a subregion, created down dropped areas, and these are the locations of numerous playas that were once pluvial lakes.

Geology

As noted, ten million years ago eruptions began and migrated from the southeast to the northwest, along what is currently known as the Brothers Fault System, which is the dominant feature of this province. This fault system is 130 miles long, stretching from the Steens Mountains to Bend. Over 100 separate rhyolitic volcanic centers located alo[...]s in this system are easily seen with aerial photographs. Crack-In-The-Ground, loca[...] just south of Four Craters Lava Field is an especially interesting example. It can easily be seen on Google map “Satellite” view.

Orr & Orr High Lava Plains 1999

Newberry Crater is located at the apex of the main Brothers Fault System where it intersects with the southwest to northeast Walker Rim Fault System and the north to south Green Ridge/Sisters aka Tumelo Fault System. It is separate and younger than the High Cascade volcanoes. Newberry is probably at the end of an eruptive cycle, given its last eruptions were rhyolitic.

Bimodal lavas are an unusual feature of the High Lava Plains. Bimodal lavas consist of basaltic lavas, and rhyolitic lavas. Basaltic lavas occur earlier in an eruptive cycle, derive from deeper, hotter sources, and contain less silica, making them typically low in viscosity, and likely to flow easily. Rhyolitic lavas derive from shallower sources, are higher in silica, more viscous, and occur later in an eruptive cycle. Basalt lavas are more common, and dominate the region. Rhyolitic extrusions and domes punctuate the fracture zones. Bimodal lavas are rare, occurring only where the earth’s crust is thin and stretched, such as is the case in Central Oregon.

The northwestern movement of eruptions over 10 million years is very striking. Was this movement of the crustal plate over hotspot, like Yellowstone? That is unlikely. If that were the case, then given the fact that the North American plate is moving west, the age progression should be exactly reversed, which it is not. The movement of activity is more likely due to a deepening of the subduction zone below eastern Oregon. As the angle of subduction placed the molten center of the subducted plate farther west, the eruptive front moved west as well.

Pleistocene Lakes

Up to approximately 11,000 years ago, the Great Basin had many large, shallow lakes due to increased moisture in the region due to the Pleistocene Ice Age. Most of these have become playas, and those located in the High Lava Plains are no exception. Prehistoric Fort Rock Lake (1400 mi^2) and Malheur Lake (900 mi^2) were the two largest in the region. The environment, as indicated by sediment records, was more lush than now, with a higher density of plants and animals. Relics left by Native Americans have been found there. During the high water of the Pleistocene, many of the lakes were interconnected as one large lake. Features such as Fort Rock, created when groundwater struck hot magma and exploded, would have been islands.

Harney basin-

Harney Basin, current location of Harney and Malheur and associated smaller lakes, was formed by downwarping and a major caldera system long since unrecognizable. This basin has no outlet- that is, it has interior drainage.

Interesting Features of the Region

Interesting features of the High Lava Plains include Hole in the Ground, Four Craters, Devils Garden, Squaw Ridge Lava Fields, Diamond Craters, a number of volcanic buttes (Pilot, Powell, Newberry Crater, Lava and Glass Butte), Lava Cast Forest, Lava Caves, Crack in the Ground and Smith Rock.

Newberry Crater is a low profile, shield volcano that is 40 miles long in a north-south direction, and 20 miles wide east to west. It is one of the largest quaternary volcanoes in the U.S. It is rather shortlived for a volcano (500,000 years). It formed a large caldera at some point, probably around 3-400,000 years ago. Its most recent eruption of obsidian (rhyolite) was about 2000 years ago, and this was a source of obsidian used by Native Americans as an important trade item. A layer of 6900 year old Mazama ash is present in the stratigraphy of the volcano, and it is helpful in dating recent eruptions. Newberry is at the center of three fault systems, at the point where they converge. It is drained by Paulina Creek to the Deschutes River. There has been intense interest in geothermal features, which will hopefully die down due to environmental concerns.

Lava Butte is a classic basalt cinder cone on the flank of Newberry Volcano. It is thus considered parasitic. It erupted about 6000 years ago in 8 separate events. It dammed and diverted the Deschutes, creating a lake to the south of Bentham Falls. Nearby Lava Cast Forest was created at this time when trees were encased in the slow moving lava, burned, and thus formed "molds" or "casts" within the actual lava.

Glass Butte is another feature that extruded large amounts of obsidian. It was a source for that valuable item for Native Americans. Crack in the Ground, located in Christmas Valley, just south of Four Craters Lava Field, is a very interesting example of recent faulting that can be seen from aerial photographs. You can literally walk down into Crack In The Ground. Smith Rock is a large tuff deposit that has been eroded by the Crooked River into a premier climbing location that is world renowned.

All summary information derived from Orr & Orr High Lava Plains 1999.

Wikipedia 2009

View showing large size of Crack-In-The-Ground

http://en.wikipedia.org/wiki/File:CrackinGround.jpg

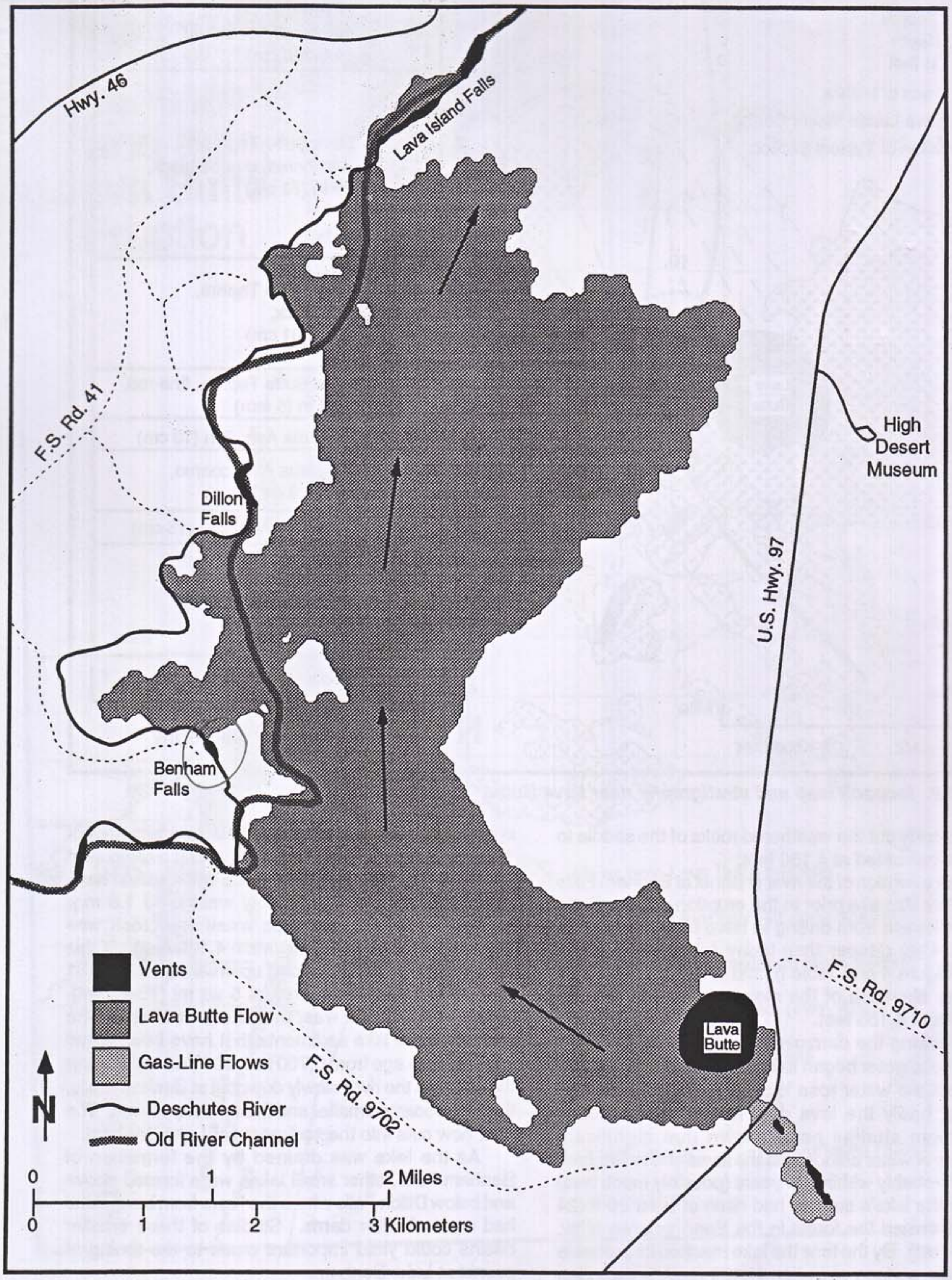


Figure 1. Lava Butte and Gas-Line Flows

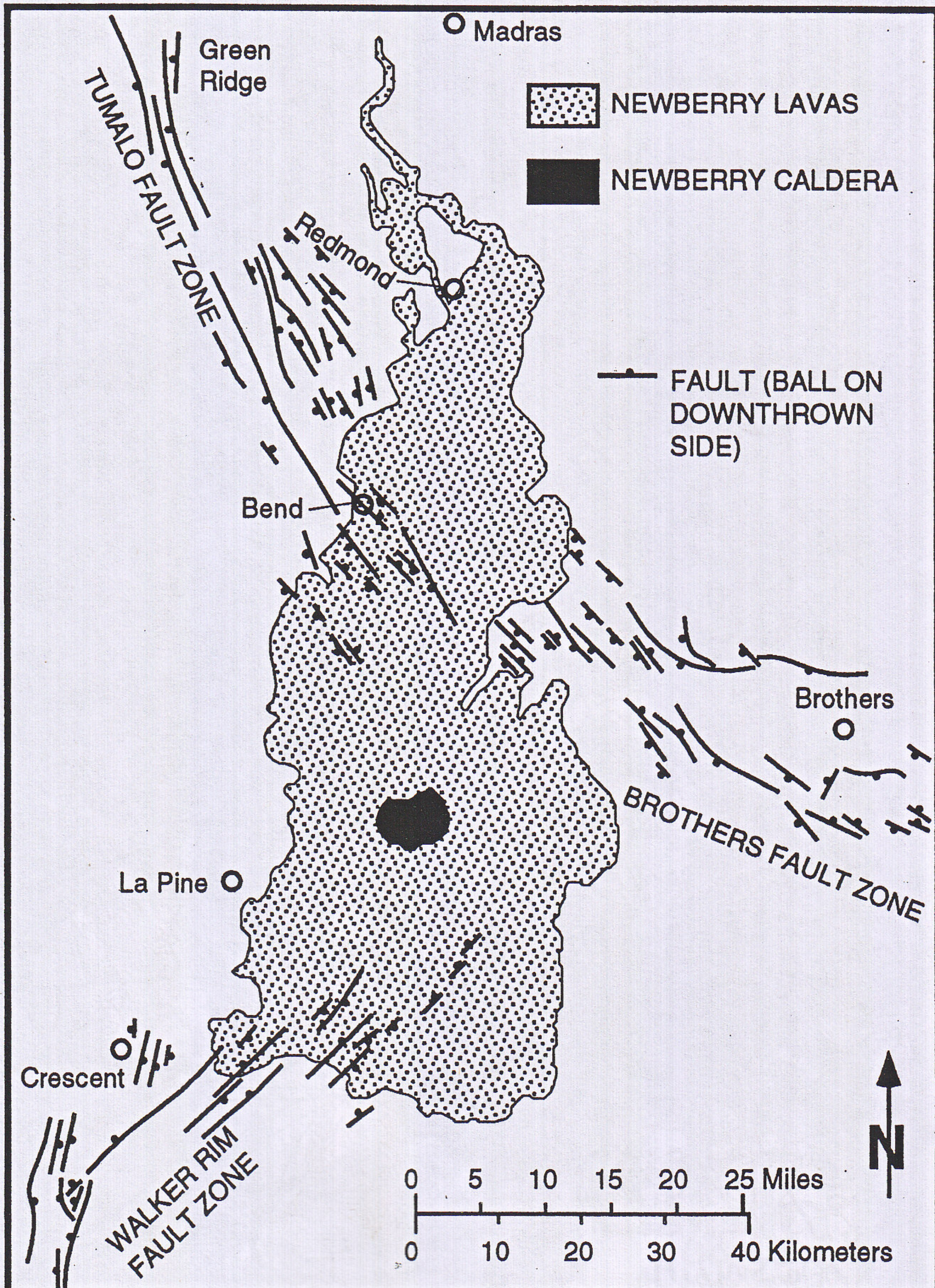


Figure 6 -- Extent of lavas from Newberry Volcano.

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Geologic Overview of Newberry Crater- annotated notes*

Newberry Crater
At Apex of Brothers (SE to NW)
Walker Rim (SW to NE)
Green Ridge/Sisters aka Tumelo (N to S)
Separate, younger, to the east of cascades
Recent eruptions rhyolitic
Indicate end of eruptive cycle
Short lived volcano, only about 500K yrs.
Low profile, shield volcano
40 mi N/S, 25 mi E/W
one of largest quaternary volcanoes in U.S.
Multiple Caldera collapses
Erupted often, lately during holocens.
3600 feet above surrounding plain
500+ sq miles
110 mi^3 volume
slopes are gentle at perimeter- basaltic, more flowable
steeper at cone
recent rhyolitic flows = less flowable

Basalt flows from Newberry
Broad plain to N from Bend to Redmond covering 270 mi^2
Summit caldera 5 mi diameter
Major ash-flow tuffs on west and NE flanks + several Caldera walls nestled
Indicate multiple collapses
Drained by paulina Lake, over low, west wall of Caldera.
Caldera
Initially Deeper
Filling in with lacustrine deposits,
Volcanic rocks, flows, domes
Pleistoncen
Only one lake,
Divided over time by eruptions

Six recent eruptive episodes in Pleistocene and Holocene

1. South Obsidian Eruptive Episode 12,000 ya
   Obsidian dome and related obsidian flow from vent along caldera ring in SE caldera

2. East Rim Eruptive Episode 11,200 ya
   lava flows, cinders, spatter from fissure on east rim of caldera

3. Interlake Eruptive Episode 7,300 ya
   rhyolitic, tephra, obsidian flows, large pumice cone, several small cones
   lasted about 200 years

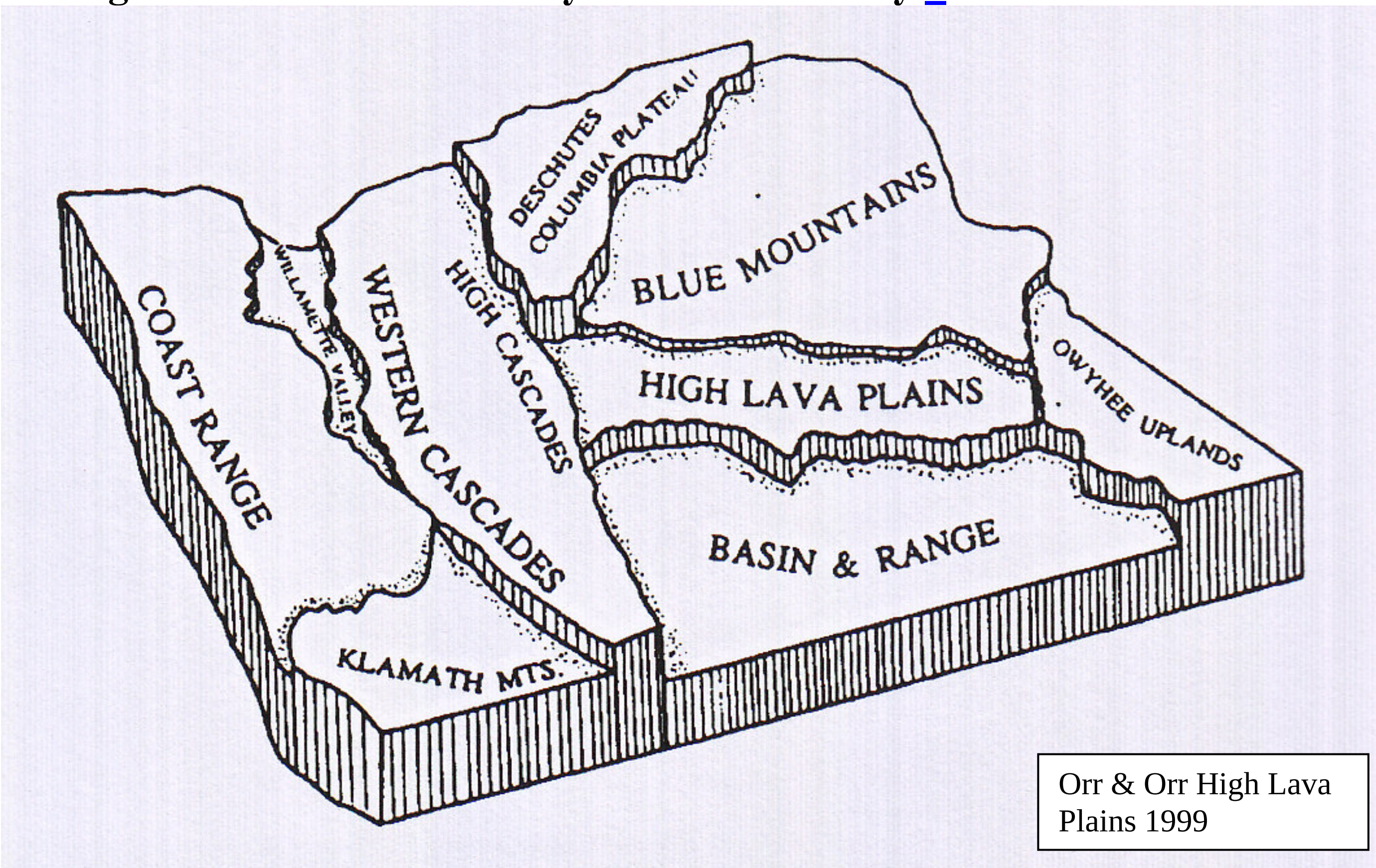
4. Northwest Rift Eruptive Episode 7,000 ya
   lava flows (basaltic andesite) and cones formed along fissures on flanks
   lasted about 50 years

5. East Lake Eruptive Episode 3,500 ya
   obsidian flows w/ pumice deposits

6. Big Obsidian Eruptive Episode 1,460 ya rhyolitic
   including Big Obsidian Flow

All notes derived from Jenson and Chitwood Overview of Newberry volcano 2000

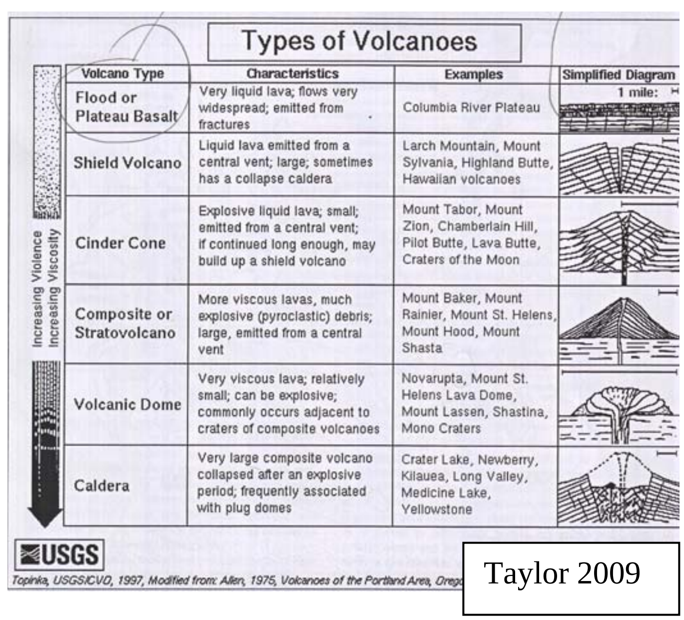
Geologic Overview of Newberry Crater- summary *



Orr & Orr High Lava Plains 1999

Newberry Crater is located at the apex of Brothers (SE to NW), Walker Rim (SW to NE) and Green Ridge/Sisters aka Tumelo (N to S) fault systems. It is separate from and younger than the High Cascades, and is located east of that region. Recent eruptions have been rhyolitic, always an indication that an eruptive cycle is close to termination. Considering that Newberry Volcano first erupted about 500,000 years ago, and that it is probably at the end of its eruptive cycle, it is a relatively short lived volcano.

Newberry is a low profile, shield vocano, about 40 miles long by 25 miles wide, and one of the largest quaternary (meaning it occurred within the last 2 million years) volcanoes in the United States. Newberry has erupted often and has undergone numerous caldera collapses. It has erupted lately, during both the Pleistocene and the Holocene epochs. It stands about 3600 feet above the surrounding plane and covers some 500+ square miles. The slopes on the flanks of the mountain are gentle, an indicator of the more basaltic early flows, while high on the mountain, the extrusion of more rhyolitic product has resulted in understandably steeper slopes from about 6000 feet elevation to the top of the Caldera at 7600 feet.



Types of Volcanoes

Volcano Type	Characteristics	Examples	Simplified Diagram
Flood or Plateau Basalt	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	
Shield Volcano	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes	
Cinder Cone	Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano	Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon	
Composite or Stratovolcano	More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent	Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta	
Volcanic Dome	Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes	Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters	
Caldera	Very large composite volcano collapsed after an explosive period; frequently associated with plug domes	Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone	

Topinka, USGS/CVO, 1997, Modified from: Allen, 1975, Volcanoes of the Portland Area, Oreg

Taylor 2009

Basalt flows from Newberry extend from Bend to Redmond and cover about 270 square miles. The summit caldera is about 5 miles in diameter. Major ash-flow tuffs on the west and northeast flanks, plus several caldera walls nestled inside each other indicate multiple caldera collapses occurred in the past.

Newberry is drained by Paulina Creek, over the low, west wall of the caldera. The caldera was initially deeper, but has filled in over time with lacustrine deposits, volcanic rocks, flows and domes. The original lake has been separated into two lakes presently- East Lake and Paulina Lake.

There have been six recent eruptive episodes in Pleistocene and Holocene:

1. South Obsidian Eruptive Episode 12,000 ya
   Obsidian dome and related obsidian flow from vent along caldera ring in SE caldera

2. East Rim Eruptive Episode 11,200 ya
   lava flows, cinders, spatter from fissure on east rim of caldera

3. Interlake Eruptive Episode 7,300 ya
   rhyolitic, tephra, obsidian flows, large pumice cone, several small cones
   lasted about 200 years

4. Northwest Rift Eruptive Episode 7,000 ya
   lava flows (basaltic andesite) and cones formed along fissures on flanks
   lasted about 50 years

5. East Lake Eruptive Episode 3,500 ya
   obsidian flows w/ pumice deposits

6. Big Obsidian Eruptive Episode 1,460 ya rhyolitic
   including Big Obsidian Flow

All text information from Jensen & Chitwood- Overview of Newberry volcano, 2000.

Table II – Summary of calendar and carbon-14 ages from Newberry Volcano area. **

Dated Feature	Carbon-14 age[1] (14C yr B.P.)	Reference	Weighted mean age (14C yr B.P.)	Calibrated age[2] (calendar yrB.P.)
BIG OBSIDIAN ERUPTIVE PERIOD				
Big Obsidian Flow	No 14C date[3]			
Paulina Lake Ashflow	1,270±60	Pearson and others (1966)		
	1,340±60	Robinson and Trimble (1983)	1,310±40[4]	1,260±90
	1,390±200	Meyer Rubin, in Peterson and Groh (1969)		
	2,054±230	Libby (1952)		
Newberry Pumice	1,720±250	Spiker and others (1978)		
(pumice-fall deposits)	1,550±120	Robinson and Trimble (1983)	1,580±110	1,460±110
EAST LAKE ERUPTIVE PERIOD				
East Lake Obsidian Flows	No 14C date[5]			
TERRACE DEPOSITS AT LITTLE CRATER CAMPGROUND				
Terrace Deposits	4,300±100	Robinson and Trimble (1983)	4,300±100	4,860±200
NORTHWEST RIFT ERUPTIVE PERIOD				
Lava Butte Flow	6,160±70	Chitwood and others (1977), Robinson and Trimble (1981)	6,160±70	7,020±140
Gas-Line Flows	5,800±150	Chitwood and others (1977); Robinson and Trimble (1981)		
	6,150±65	Robinson (1977); Chitwood and others (1977)	6,100±60	6,940±80
North Sugarpine Flow	5,870±60	Robinson and Trimble (1981)	5,870±60	6,720±80
Forest Road Flow	5,960±100	Peterson and Groh (1969)	5,960±100	6,810±130
Lava Cast Forest Flow	6,150±210	Peterson and Groh (1969)		
	6,380±130	Peterson and Groh (1969)	6,320±110	7,210±150
Lava Cascade Flow	5,800±100	Peterson and Groh (1969)	5,800±100	6,640±160
North Summit Flow	6,090±60	Peterson and Groh (1969)	6,090±60	6,910±100
Surveyor Flow	5,835±195	Swanberg and others (1988)		
	6,080±100	Peterson and Groh (1969)	6,030±90	6,880±120
INTERLAKE ERUPTIVE PERIOD				
Central Pumice Cone	No 14C date[6]			

Bimodal
Rhyolitic – either explode or thick dome – more silica
Basaltic – thinner local flows – less silica

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Game Hut Obsidian Flow	No 14C date[7]			
Interlake Obsidian Flow	No 14C date[8]			
East Lake Tephra	6,220±200 6,500±300 6,550±300	Meyer Rubin and W.E. Scott, unpublished data, 1985. Meyer Rubin, in Linneman (1990) Meyer Rubin, in Linneman (1990)	6,400±130	7,270±120
CLIMATIC ERUPTION OF MT. MAZAMA				
Mazama Ash	6,845±50[9]	Bacon (1983)	6,845±50	7,630±50
NEWBERRY CRATER ARCHAEOLOGY				
Oldest domestic structure	8,460±110 8,540±90 8,670±110	Connolly (1999) Connolly (1999) Connolly (1999)	8,555±62[10]	9,530±40
Earliest dated human occupation	9,920±470	Connolly (1999)	9,920±470	11,010±1300
EAST RIM ERUPTIVE PERIOD				
East Rim Fissure	10,000±500	Meyer Rubin, in Linneman (1990)	10,000±500	11,160±1200
FORT ROCK CAVE ARCHAEOLOGY				
Earliest dated human occupation	13,200±720	Bedwell (1973)	13,200±720	15,740±1100

** Modified from MacLeod and others (1995).
[1] Carbon-14 ages based on Libby half-life of 5,568 yrs. Years before present (yr B.P.) measured from 1950 A.D.
[2] Generalized from program in Stuiver and Reimer (1993) that computes intercepts and range (one confidence interval). Radiocarbon age curve not linear and may have multiple possible calendar ages (intercepts) for a given carbon-14 age. Calibrated age as reported here is midpoint between oldest and youngest intercepts rounded to nearest ten years; reported error is range (one confidence interval as calculated by the program).
[3] Hydration-rind age of 1,400 calendar years in Friedman (1977) is too old based on stratigraphic position. Big Obsidian Flow overlies Paulina Lake Ashflow which has a calibrated age of 1,260 calendar years.
[4] Weighted mean age does not include Libby's (1952) determination of 2,054 yr B.P.
[5] Hydration-rind age of 3,500 calendar years in Friedman (1977).
[6] Hydration-rind age of 4,500 calendar years in Friedman (1977) is too young based on stratigraphic position. Central Pumice Cone deposits lie between East Lake Tephra and North Summit Flow which have calibrated ages of 7,270 and 6,910 calendar years respectively.
[7] Hydration-rind age of 6,700 calendar years in Friedman (1977) is too young based on stratigraphic position. Flow is younger than Central Pumice Cone. Central Pumice Cone deposits lie between East Lake Tephra and North Summit Flow which have calibrated ages of 7,270 and 6,910 calendar years respectively.
[8] Hydration-rind age of 6,700 calendar years in Friedman (1977) is too young based on stratigraphic position. Flow is younger than Central Pumice Cone. Central Pumice Cone deposits lie between East Lake Tephra and North Summit Flow which have calibrated ages of 7,270 and 6,910 calendar years respectively.
[9] Weighted mean age of four charcoal samples (Bacon, 1983): 6,780±100; 6,830±110; 6,880±70; 6,840±100.
[10] Weighted mean age of three charcoal samples from burnt house posts (Connolly (1999).

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Deschutes-Columbia Plateau- notes *

Volcanic province
63,000 mi^2
Oregon, Wa, ID
Surrounded by mtns
- Okanogan north
- Cascades west
- Blue Mtns south
- Clearwater east

200 mi L x 100 mi W
Merges w/Deschutes Basin
Slopes north, toward Columbia.
Primary rivers in Oregon
- Columbia- 3rd largest U.S.
  - Deschutes
  - John Day
  - Umatilla
  - Willow, Butter Creeks
  - Starts in BC rockies, south
  - Bend at tri cities
    - Heads west
  - Total watershed 295,000 mi^2
- Deschutes
  - Crooked
  - Metolius
  - Headwaters Mt. Bachelor
  - 250 miles long
  - intricate, deep canyons into horizontal plateau

Geologic Overview
- Somewhat general and confusing overview by Orr and Orr in places (Deschutes area)
- 2nd largest basalt flow in world
- source vents in NE Oregon, SE Washington, Adjacent Idaho
- 17.5 to 6 mya
- giant, flat plateau
- The edge of CRB's in Deschutes area was N/S just barely west of Deschutes,
  - blocking eastern movement in Deschutes basin
    - Deschutes and other streams formed alluvial plan in what is now Deschutes basin
    - Filled in this area with ash and lavas from ancestral cascades
  - Later, deposition source on top of these deposits was from local cones in Pliocene.
  - Also lakes created during Pliocene- lacustrine deposition in places
  - Subsequent uplift caused deep cutting by rivers
    - Metolius, crooked, Deschutes and smaller tributaries
  - Volcanism ceased after flows from Newberry and related vents
- Missoula Floods impacted entire CRB area
    - Channeled scablands
    - Scouring of Columbia Gorge
    - Deposition of flood materials in Deschutes as far as Maupin (45 mi up from gorge)

Geology

John Day and Clarno formations

- Small portions extend into Deschutes-Columbia Plateau from south
- We see a lot of this as we travel from Trout Creek down to about mile 60
- Old, poorly consolidated, mix of various volcanic product prior to CRB
- John Day 25-17 mya- lighter colored, appears more pumice, etc
- Clarno 45-35 mya- darker, more basalts, also reworked chemically by geothermal waters

Oldest rock carried by streams from western part of province

- Single stone 250 my old
- From eastern Blue Mtns accretion of exotic terrain (islands crashing into the continent)

Main focus is on CRB's

- Mid-late Miocene 17.5- 6 mya
- Vents in SE. Wa/ NE Or/ ID
- Avg 1 @ 35k yrs
- 100 mi^3 avg flow
- 500 mi^3 larger flows
- up to 30 mph
- 42,000 mi^3 total volume
- several flows up to 200' thick
- Diagrams show distribution and shape
- 3d diagram shows 3d shape.
- The thinning at edges suggest lava was extruded into basin
  - Basin subsided progressively with succeeding flows.
- More extensive flows-
  - Decades to cool
- Patterns of cooling
  - Colonnade (from greek temple nomenclature)
    - Lower section, pencil like vertical columns perpendicular to surface
  - Entablature
    - Typically 4/5 of thickness of flow
    - Columns in multi-directions
    - Top of entablature may be vesicular- hot escaping gas
- Ancestral Columbia River
  - Pushed northward by extrusions of basalt that were
    - Pinched N-S
      - Caused E-W fold
    - River ends up in one of the E-W folds
      - Farther north than where it started
- Below CRB deposits
  - Poorly understood
    - After all, CRB's are 3 miles thick
- Deschutes Basin
  - See map
  - Filled from 16-12 Mya with Cascades volcanic material
  - Concurrent with CRBs.
  - CRB ended physically just West of Deschutes,
    - So, simtustus laid down between Cascades and CRB
      - West of CRB's, west of Deschutes
        - Must be why we didn't see them
  - 8 Mya
    - more volcanics and volcanic sediment from early Cascade volcanoes
    - basalt, andesite, ash up to 2000' thick on west side of basin

- stopped around 4 Mya
- streams began to cut into basin

Uplift- not specifically stated, but it definitely occurred

4-2 Mya
- numberous shield volcanoes and flows in Deschutes and Crooked basin
- filled in and blocked river many times
- river moves around, re-establishing new course

1.6 Mya
- More local vents plug Metolius, Deschutes, Crooked rivers with basalt
  - Up to 800’ in places.

500k ya start of Newberry w/events up thru Lava Butte 6k ya
- variety of flows as far as Redmond
  - block local rivers in various places

Last 1 million years, rivers have recut or moved channels.

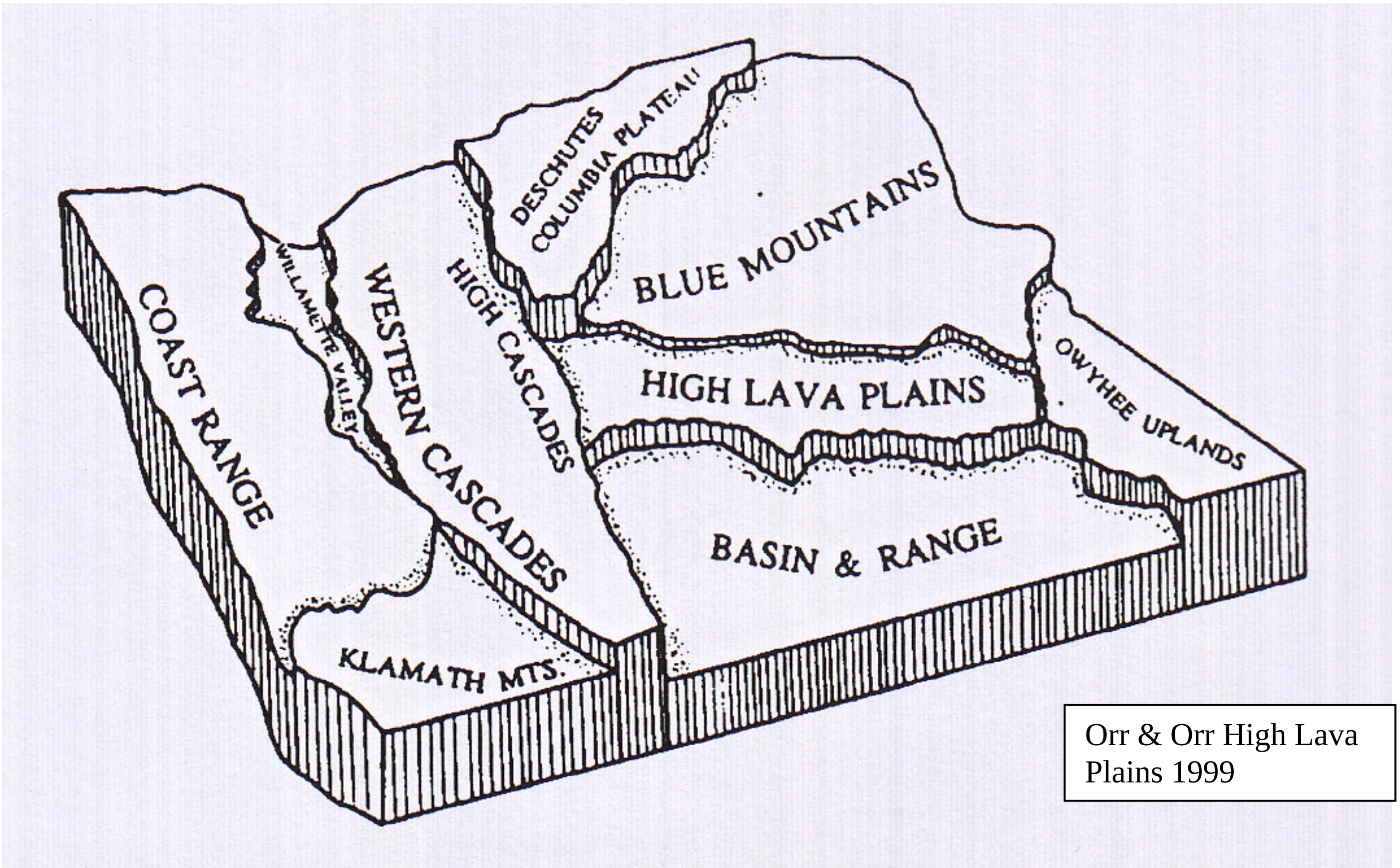
Missoula Flood
- Deposits as far as Maupin

Details of times of CRB flows included in chart
Mechanism or cause of CRB’s thought to be Back arc spreading- see diagram

Interesting Stuff

Once was a lake in vicinity of Terrabone (crooked river bridge)
67’ thick diatomaceous earth deposit from fresh water diatoms
Metolius Springs
- Ancient Metolius covered and hemmed in by volcanic flows, lignumbrite, scarps.
- Black Butte arose in the middle of the Metolius valley, inundating ancient river
- Now arises from underneath Black Butte

Deschutes-Columbia Plateau- summary *



Orr & Orr High Lava Plains 1999

In general the Deschutes-Columbia Plateau is a volcanic province. Its helpful to consider that when we talk about the portion located in Oregon, we are really referring to a small part of the whole Columbia River Plateau which covers much of eastern Washington, a large part of northern Oregon and parts of eastern Oregon as well as adjacent western Idaho. It is the second largest basalt flow in the world. This region covers 63,000 square miles in Oregon, and is bounded by the Okanogan Highlands to the north, the Cascades to the west, parts of the Blue Mountains to the south and the Clearwater Mountains in Idaho. The Columbia River Plateau, roughly 200 miles long and 100 miles wide, merges with the Deschutes basin. In Oregon, this province slopes gently toward the Columbia River.

The Columbia is the third largest river in the United States, with tributaries from the Deschutes-Columbia Plateau in Oregon consisting of the Deschutes, John Day and Umatilla rivers as well as Willow and Butter creeks. The Columbia starts in the Rocky Mountains of British Columbia, flows south, makes a large Bend in the Tri-Cities area of Washington and then heads west down the Columbia River Gorge to Portland. It then makes a northern bend, turning back westward along its final segment to the Pacific. The Columbia River watershed is approximately 295,000 square miles.

The Deschutes River is about 250 miles long, flows north along the eastern edge of the High Oregon Cascades and has the Crooked and Metolius rivers as its main tributaries. All of these rivers have carved deep, intricate canyons into the horizontal plateau.
Primary rivers in Oregon

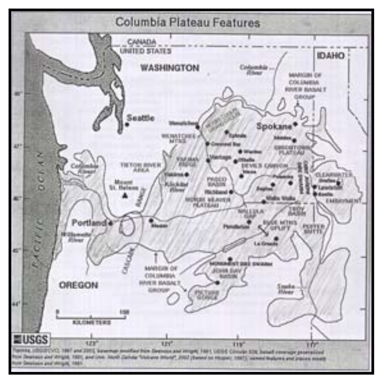
Geologic Overview

As mentioned previously, the Columbia River Basalts (CRBs) comprise the second largest basalt flow in the world. They emanated from source vents in northeast Oregon, southeast Washington, and adjacent Idaho from 17.5 to 6 million years ago, creating a giant, flat plateau. The edge of the CRBs in the Deschutes basin stops just west of the Deschutes river and runs directly north-south. This provided a barrier to eastward movement of deposition in the Deschutes basin. The Deschutes and other streams formed an alluvial plain in what is now the Deschutes basin. This area was continually filled in with ash and lavas from the ancestral Cascades.

Later depositions on top of these deposits were from local volcanic vents and cones in the Pliocene epoch. Lakes were created at various times during the Pliocene and lacustrine deposition occurred. Subsequent uplift in this area resulted in deep cutting by the Metolius, Crooked and Deschutes rivers and smaller tributaries. Volcanism ceased in this area after flows from Newberry Crater and related vents (most recent about 6000 ya, meaning it really hasn't stopped, its probably just taking a break). The Missoula Floods impacted the a huge portion of the Columbia River Plateau, creating the scablands of eastern Washington, scouring the Columbia Gorge and making depositions in a variety of places as floodwaters receded, overflowed constrictins or as glacial erratics melted out of large chunks of water transported glacial ice. Flood materials are found as far up as Maupin on the Deschutes River.

Geology

John Day and Clarno formations have small portions that extend into this province from the Blue Mountains in the south. We see a lot of this as we travel from Trout Creek down to about mile 60 on the Deschutes River. These formations are old, poorly consolidated mixes of various volcanic product deposited prior to CRBs. The John Day formation is 25-17 million years old, is generally light colored (as in pumice) although it contains some areas that are darker- probably basaltic in origin. The Clarno formation is 45-35 million years old and is darker, with more basalts, many of which have also been reworked chemically by geothermal waters intruding into the formation.



The oldest rock in the province, carried there by streams from the Blue Mountains to the west, is a single stone 250 million years old. This is part of accretion of exotic terrains in the ancient geologic history, as eastward moving island chains collided with the westward moving North American Plate.

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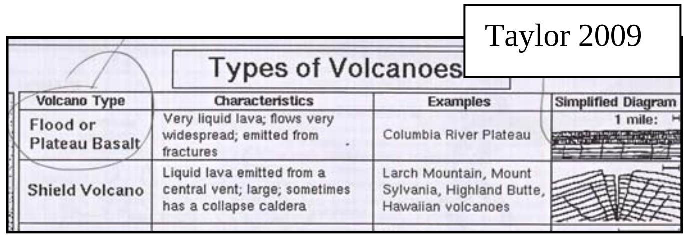
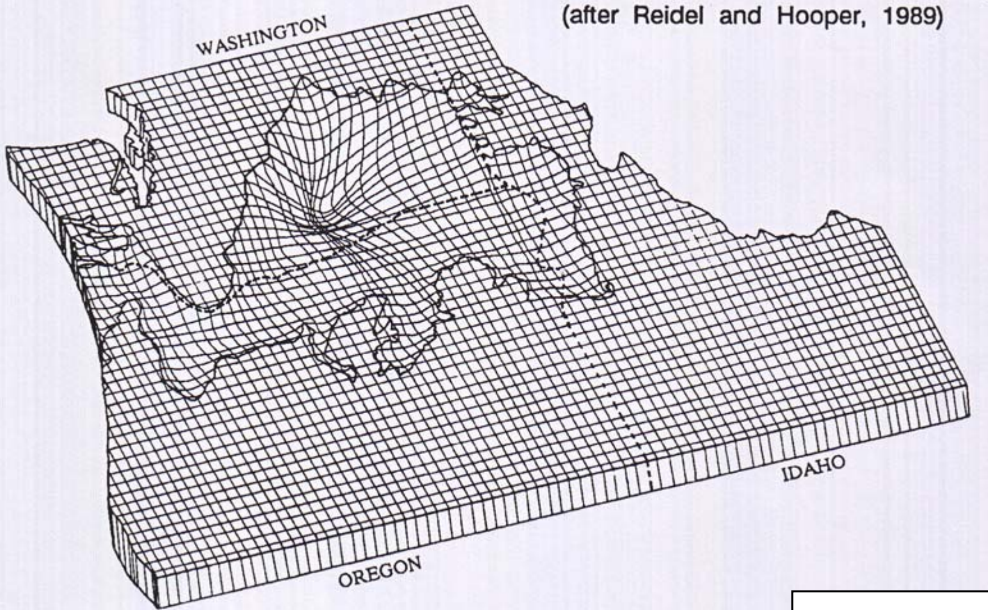


Types of Volcanoes

Volcano Type	Characteristics	Examples	Simplified Diagram
Flood or Plateau Basalt	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	1 mile:
Shield Volcano	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes	

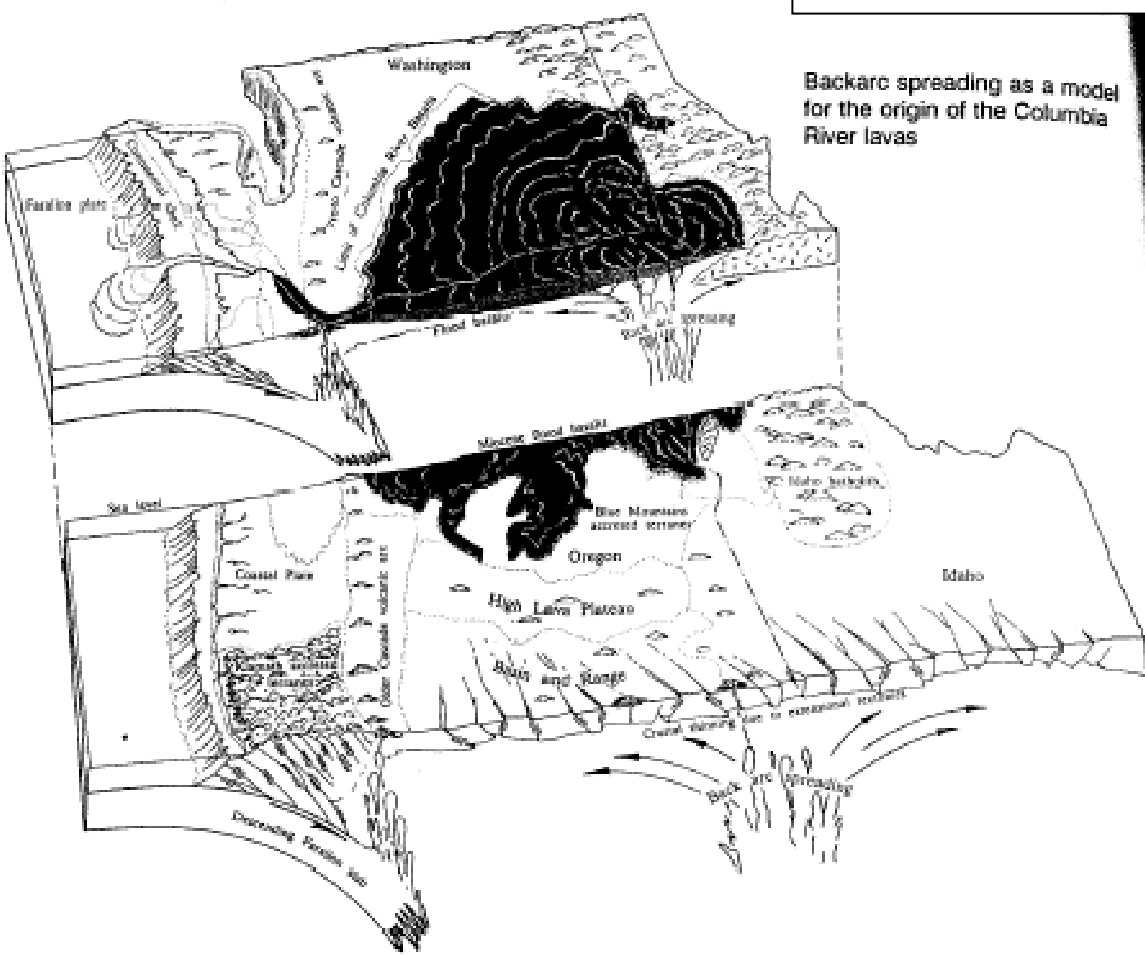
The main focus in any discussion of the Deschutes-Columbia Plateau is on CRBs. These occurred in the mid to late Miocene epoch from 17.5 to 6 million years ago from the vents described above. On average, a flow occurred abut every 35,000 years. A typical flow would have been about 100 cubic miles although flows larger than 500 cubic miles occurred. Some of these moved up to 30 miles per hour. Together, all of the CRBs take up 42,000 cubic miles. Several flows occurred that were over 200 feet thick. See the diagrams below for a good view of exact distribution and shape, including depth of the entire set of flows. The cause of the CRB flows is thought to be a process called Back Arc Spreading, demonstrated in the diagram below.
The thinning at edges of the CRB's suggest the lava was extruded into a basin. The basin continued to subside progressively with succeeding flows, due to the enormous mass. The more extensive CRB flows may have taken decades to cool.

The Columbia River Basalt Group develops its maximum thickness of nearly 15,000 feet under the Columbia Plateau near Yakima, Washington (after Reidel and Hooper, 1989)

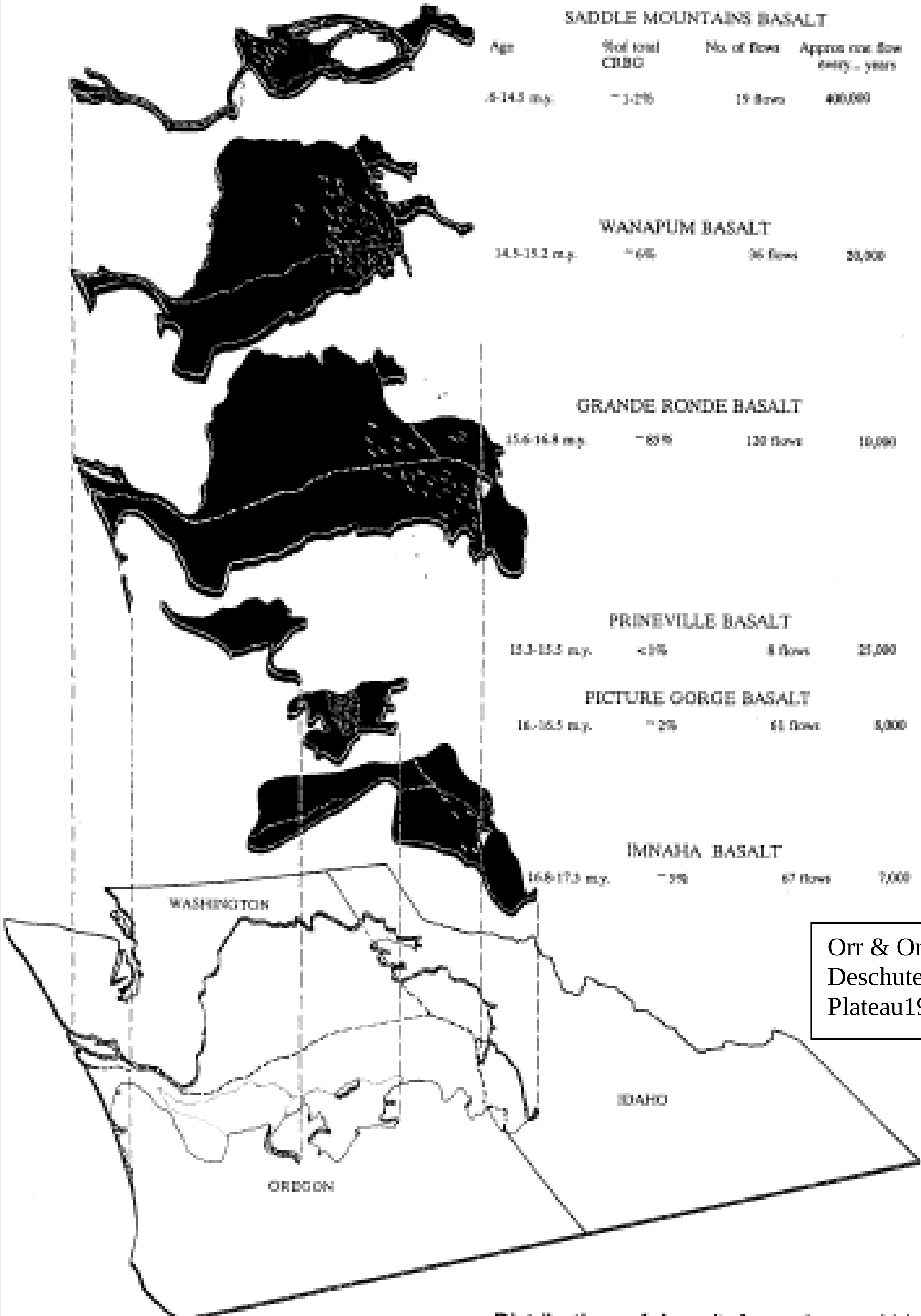


Orr & Orr Overview of Deschutes-Columbia Plateau1999

132 Deschutes-Columbia Plateau



Backarc spreading as a model for the origin of the Columbia River lavas



Orr & Orr Overview of Deschutes-Columbia Plateau1999

Distribution of basalt formations within the Columbia River Group (after Beeson and Moran, 1979; Beeson, Tolan, and Anderson, 1989)

Stratigraphic Subdivision of Columbia River Basalt Group (CRBG)

SERIES		GROUP	SUB-GROUP	FORMATION (Age, Volume, % of CRBG)	MEMBER	MAG*
Miocene	Upper	Columbia River Basalt Group	Yakima Basalt SubGroup	Saddle Mountain Basalt (14–6 Ma, 2,400 km3 volume, 1.5% of CRBG)	Lower Monumental Member	N
					Ice Harbor Member	N,R
					Buford Member	R
	Middle				Elephant Mountain Member	R,T
					Pomona Member	R
					Esquatzel Member	N
					Weissenfels Ridge Member	N
					Asotin Member	N
					Wilbur Creek Member	N
					Umatilla Member	N
				Wanapum Basalt (15.5–14.5 Ma, 10,800 km3 volume, 6.0& of CRBG)	Priest Rapids Member	R3
					Roza Member	T,R
					Frenchman Springs Member	N2
					Eckler Mountain Member	N2
				Grande Ronde Basalt (17–15.5 Ma, 151,700 km3, 87%)		N2
	Lower					R2
				Picture Gorge Basalt		N1
						R1
				Imnaha Basalt (17.5–17 Ma, 9,500 km3 volume, 5.5% of CRBG)		R1
						T
						N0
						R0

* Magnetic Polarity:
N, normal; R, reversed; T, transitional; subscripts denote magnetostratigraphic units

USGS *Topinka, USGS/CVO, 1997, Modified from: Swanson, et.al., 1989, AGU Field Trip Guidebook T106*

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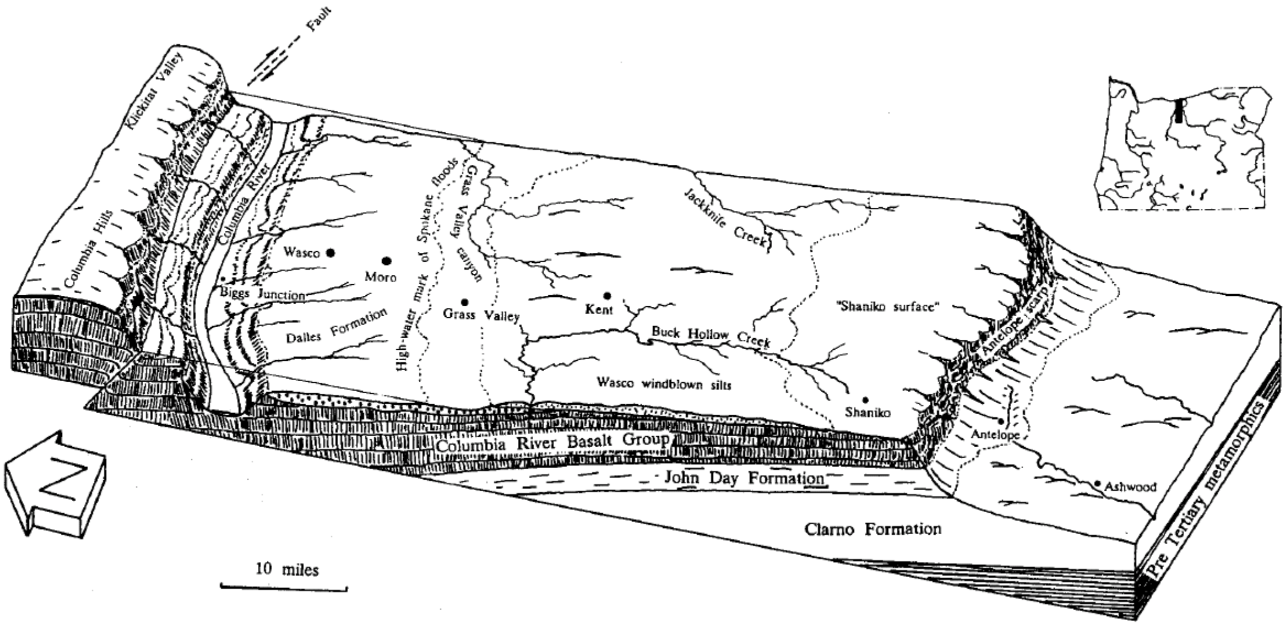


Block diagram across the Columbia River just east of The Dalles

Orr & Orr Overview of Deschutes-Columbia Plateau1999

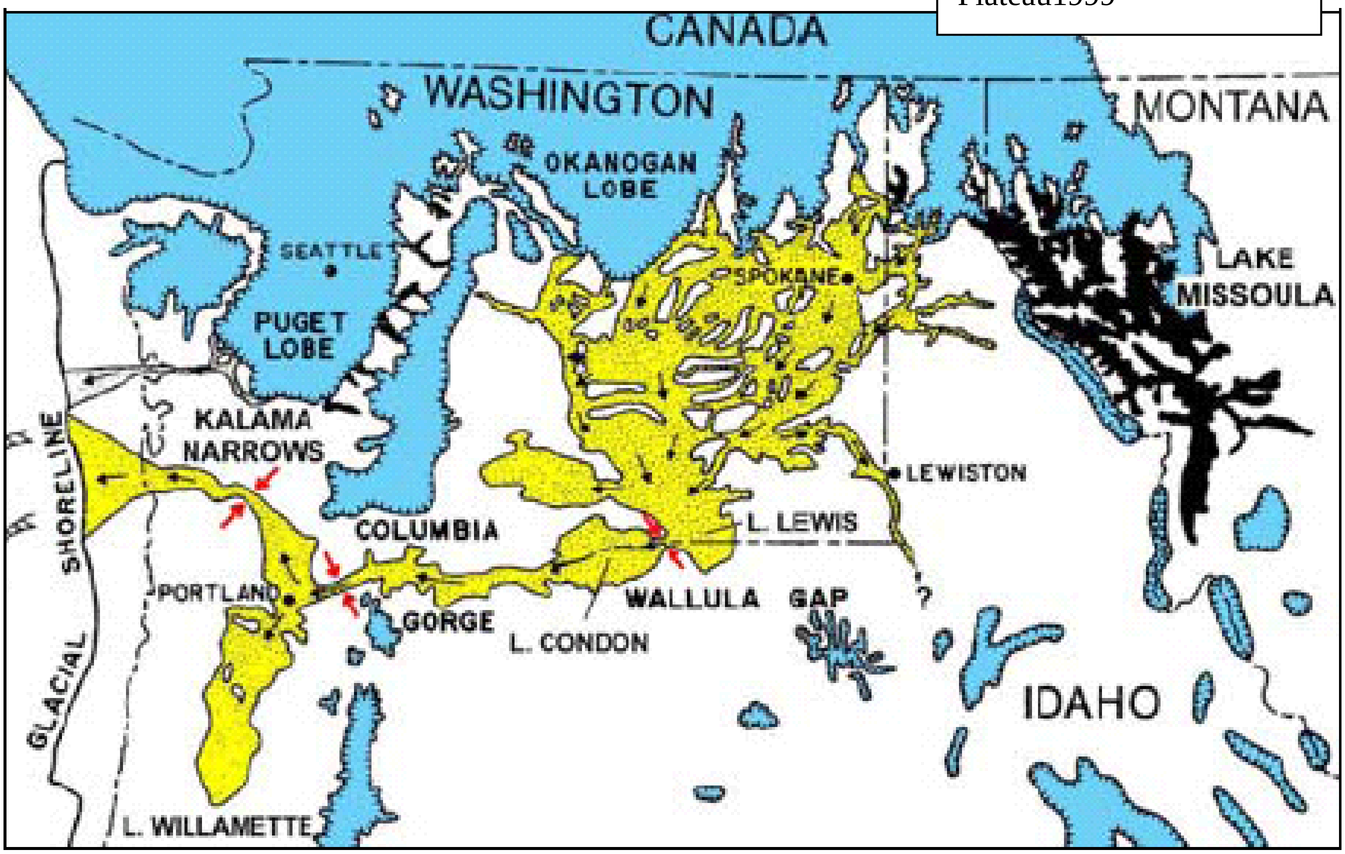


Figure 4—Flood discharge across Idaho, Washington, and Oregon.

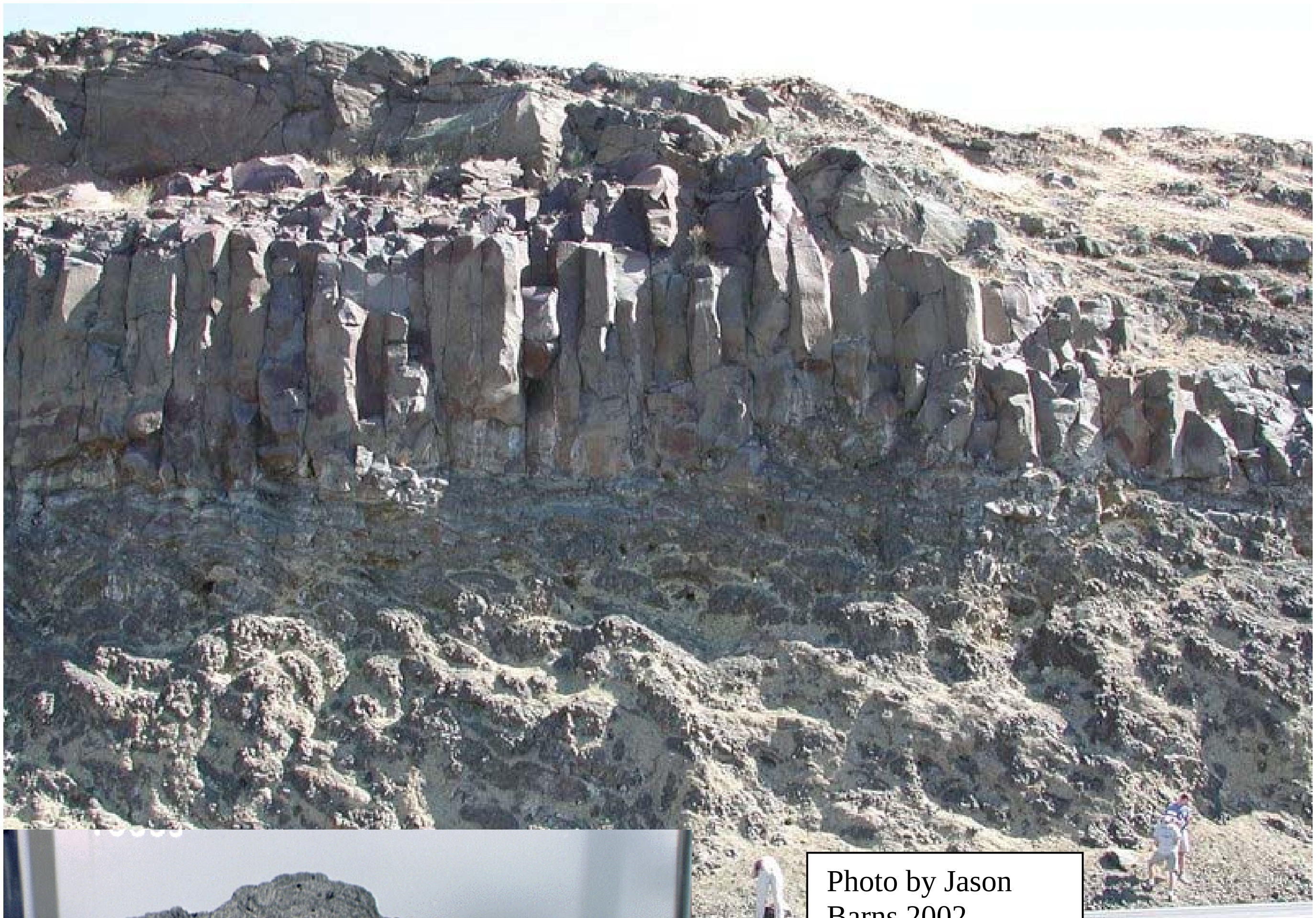


Photo by Jason Barns 2002

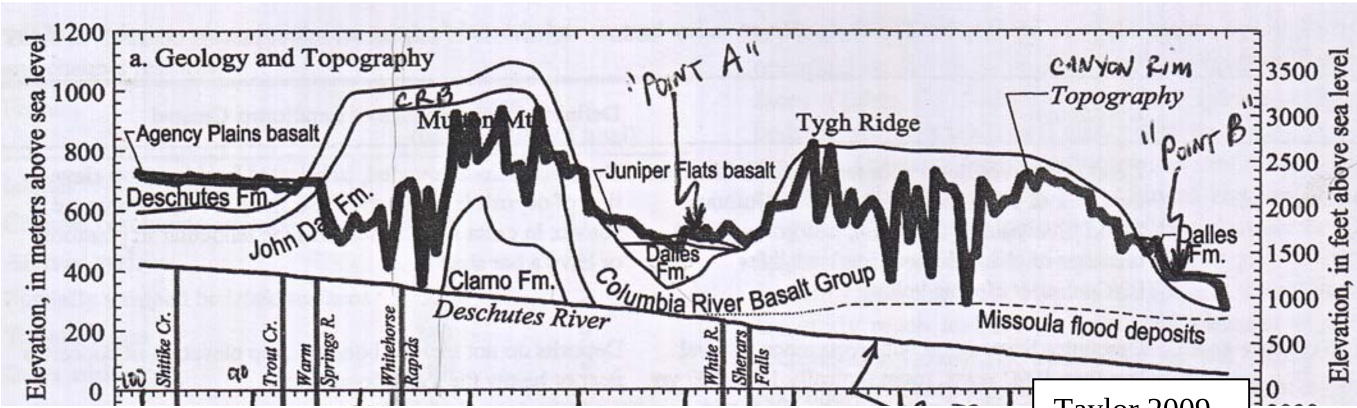
rock.blogspot.com/2007

Patterns of cooling affected the physical formation of basalt rock. Typically the lower section of a flow forms a colonnade (from greek temple nomenclature) consisting of large, pencil like vertical columns perpendicular to the surface of the flow. The upper section of a flow forms entablature, which is typically 4/5 of the flow, with multi-directional columns. The top of entablature may be vesicular due to the escaping of hot gases.

The ancestral Columbia River was pushed northward by extrusions of basalt that were pinched in a north-south direction. This pinching caused east-west folding of the basalts, and the river was eventually confined to one of these folds, ending up farther north than where it started.

The rock below the CRB deposits is poorly understood. After all, it is buried beneath up to 3 miles of basalt.

Deschutes Basin



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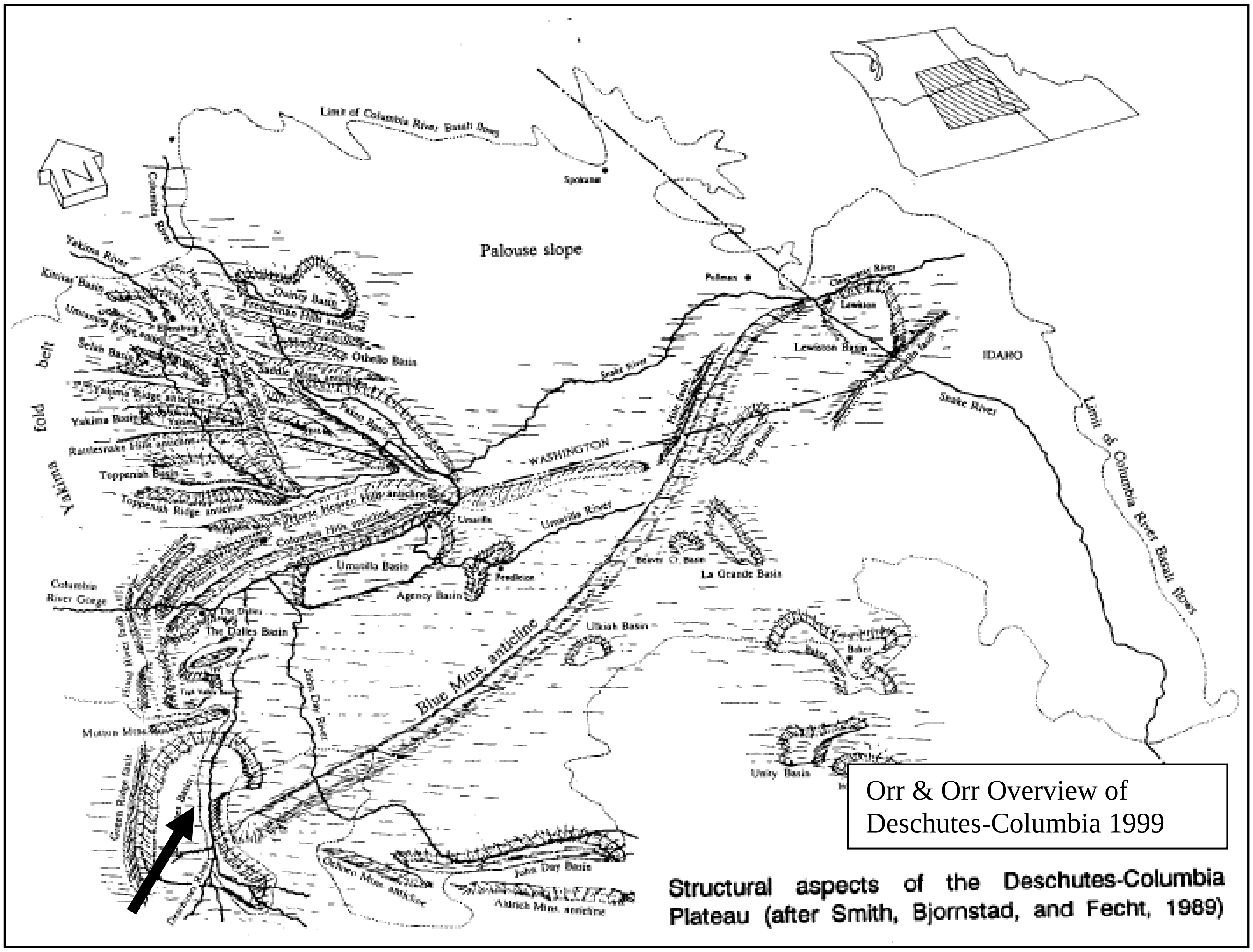
The Deschutes basin (see map) was filled from 16 to 12 million years ago with Cascades volcanic material. This had to have been concurrent with CRB deposits. The CRBs ended in a north south line, just west of the current location of the Deschutes River. Simtustus formation deposits were laid down between the Cascades and the western edge of the CRBs, filling in that area.

Eight million years ago, after a break of about 5 million years, more volanics and volcanic sediment from the early Cascade volcanoes covered the area with basalt, andesite and ash, up to 2000 feet thick on the western side of the basin, down to about 50 feet thick toward the east, at the beginning of the Ochoco mountains. This deposition stopped about 4 million years ago. From four to two million years ago numerous shield volcanoes and flows occurred in the Deschutes and Crooked river basins. These rivers were filled in and blocked many times. About 1.7 million years ago more local vents erupted and plugged the Metolius, Deschutes and Crooked rivers with basalt, up to 800 feet in places. About 500,000 years ago, Newberry volcano and related events added flows to the area, up to about 6500 years ago, in the Lava Butte flow. Again, rivers were blocked and their courses adjusted. In the last 1 million years, all the rivers in this area have re-cut or moved channels continuously.

Deep basalt flow on the Crooked River

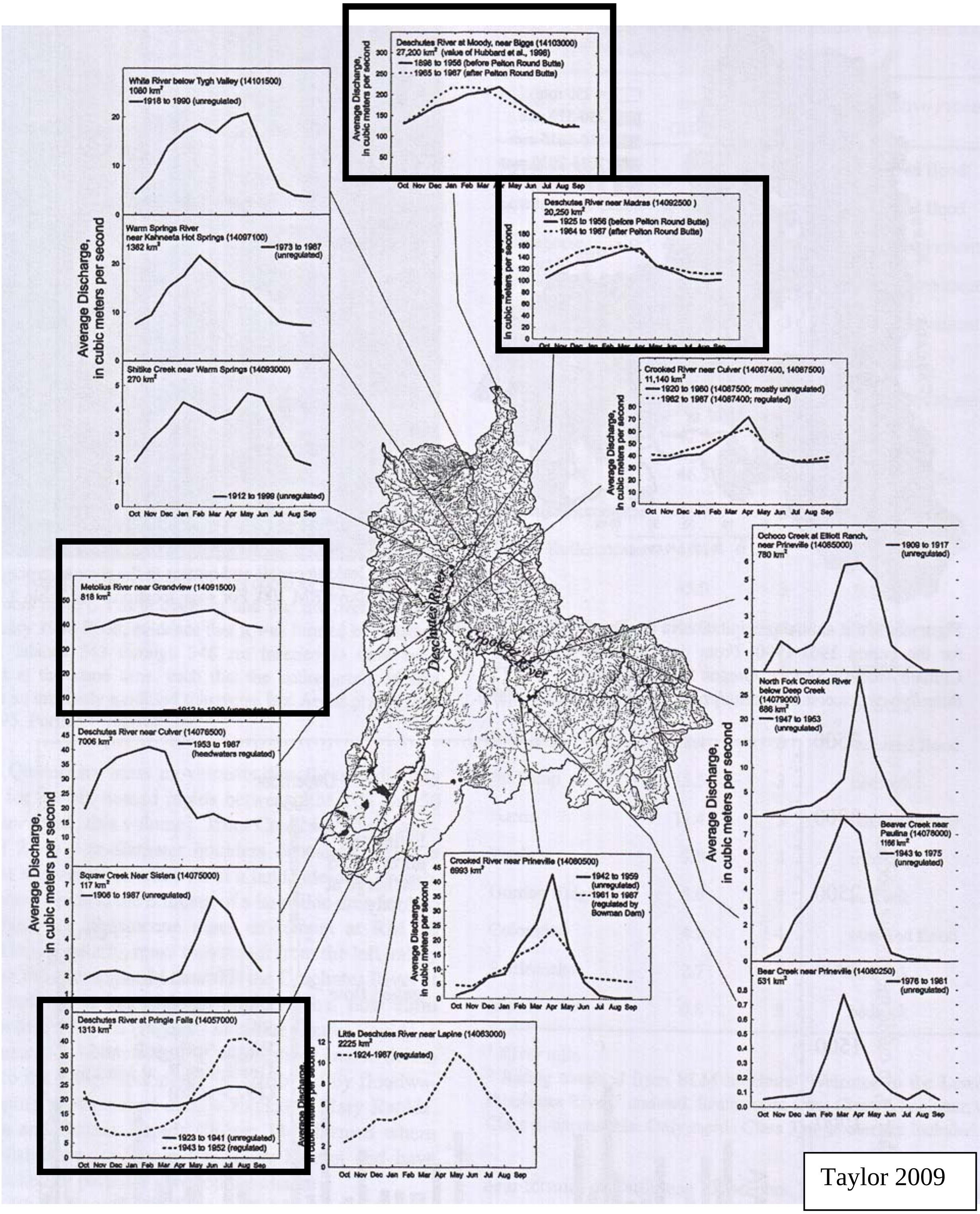
BridgePros 2009



Orr & Orr Overview of Deschutes-Columbia 1999

Structural aspects of the Deschutes-Columbia Plateau (after Smith, Bjornstad, and Fecht, 1989)

Note western edge of CRBs run just to the west of the current location of the Deschutes in the main Deschutes basin.



The graphs with heavy lined frames show annual flow and demonstrate the steadiness of the Deschutes and Metolius Rivers. Both of these rivers have groundwater from the Cascades as their main source, rather than direct precipitation or snow melt.

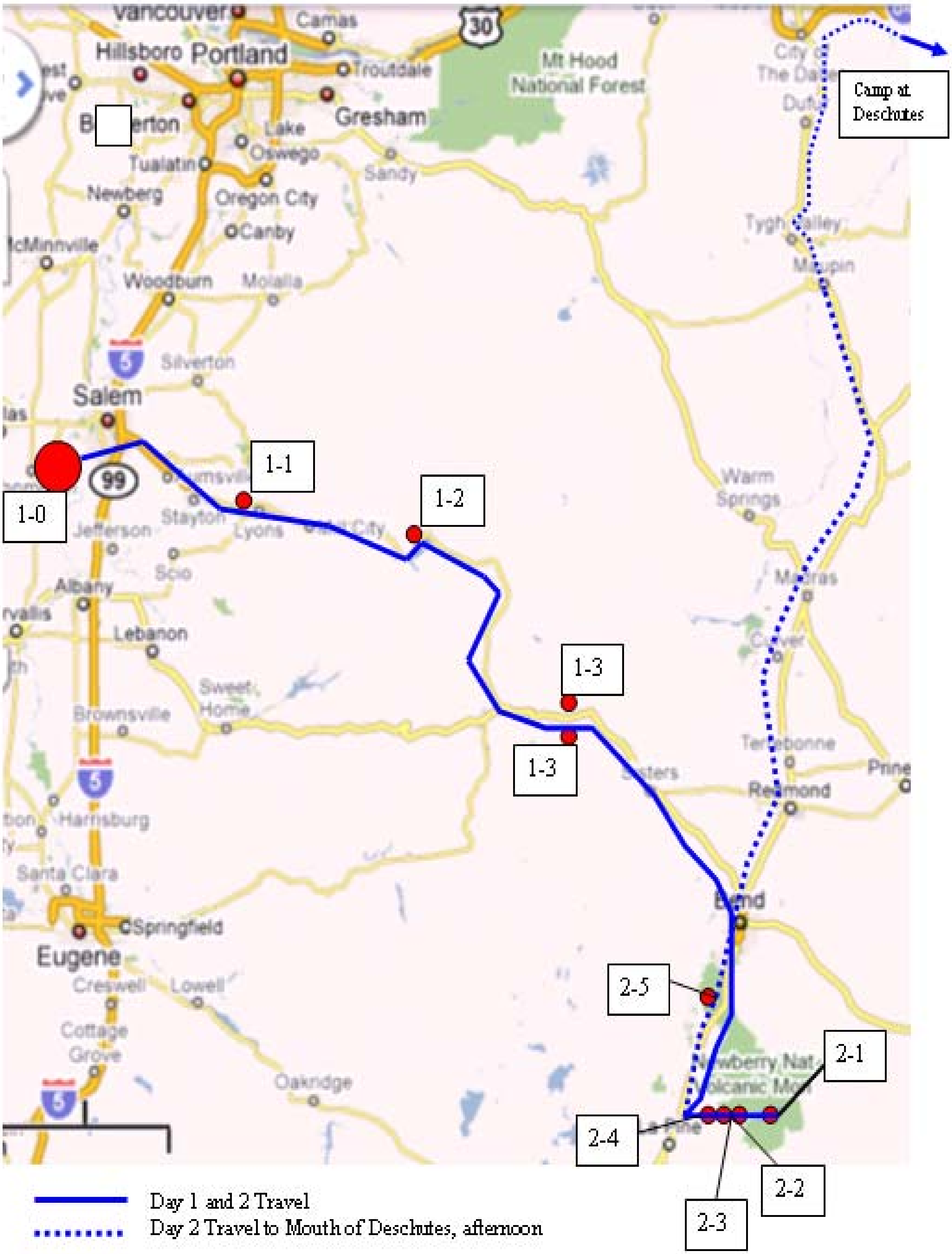
Interesting Stuff

There was at one time a lake in vicinity of Terrabone (crooked river bridge) that deposited 67 feet of diatomaceous earth. This was completely mined.

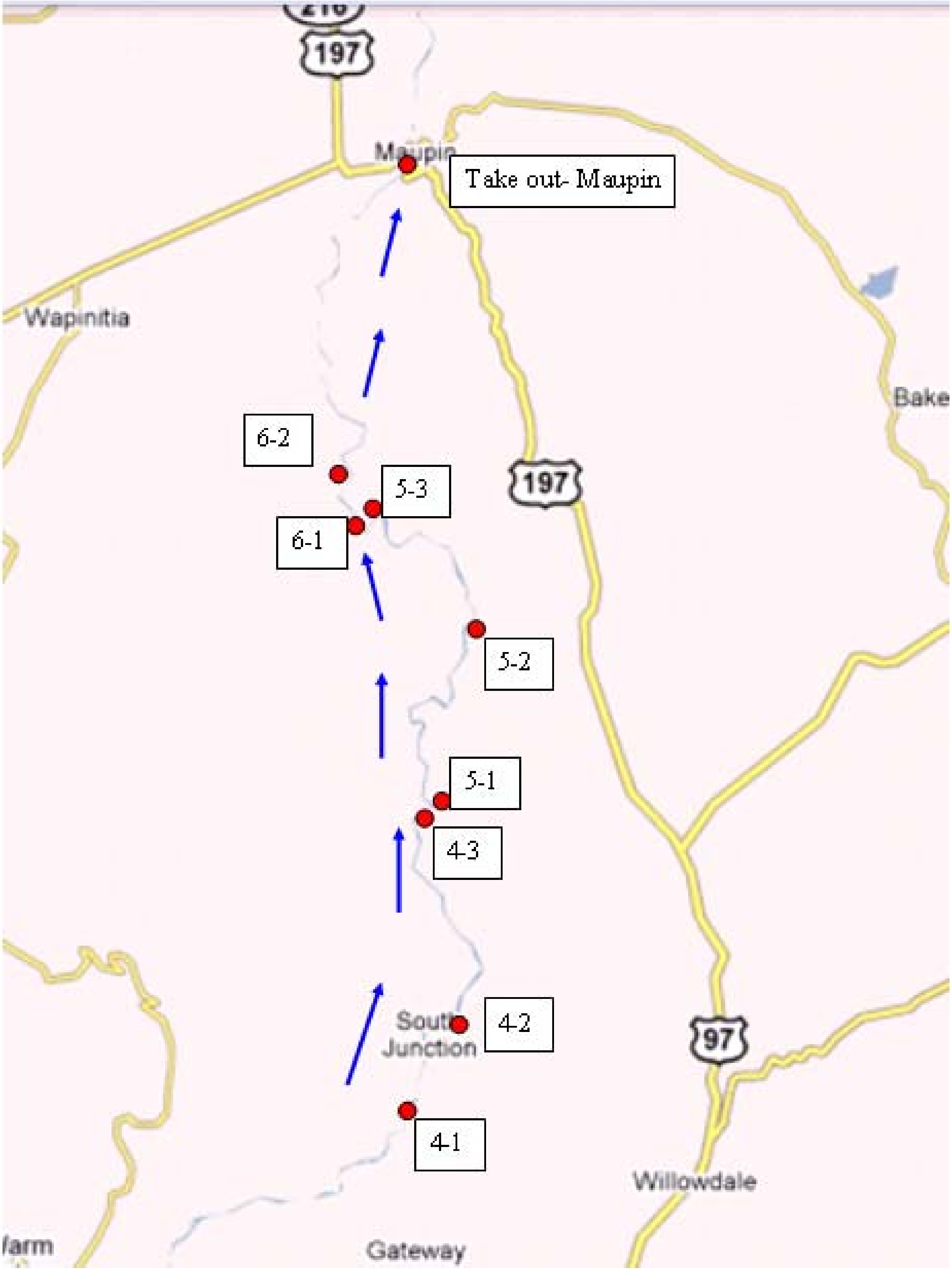
Metolius Springs

The ancestral Metolius River was covered and hemmed in by volcanic flows, lignumbrite and scarps. Black Butte arose in the middle of the Metolius valley, inundating the ancient river. As a result, two springs, Metolius Springs, arise at the northern foot of Black Butte, and form an “instant” river.

Field Stop Descriptions *

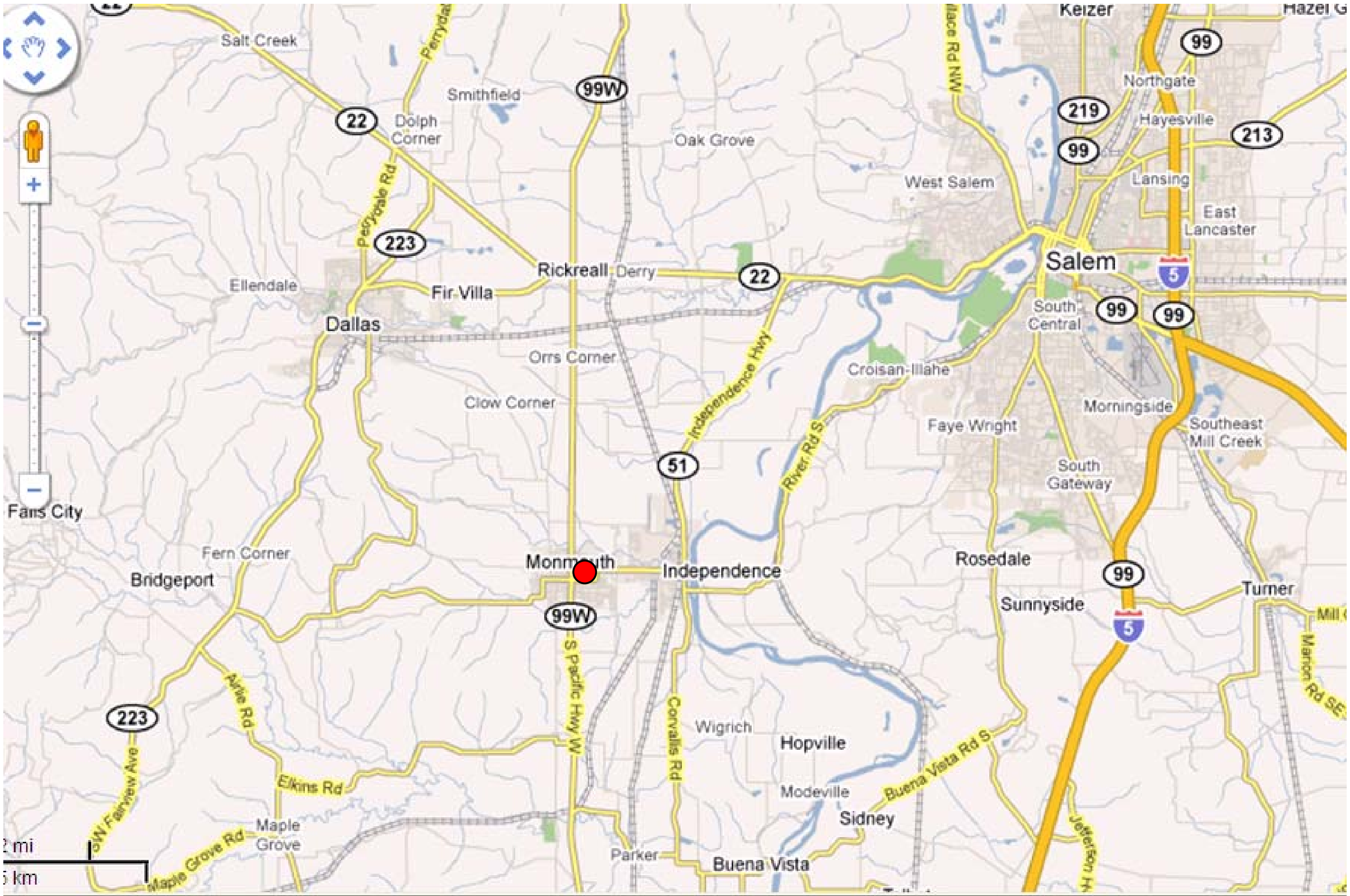

Vancouver
Camas
30
Hillsboro
Portland
Troutdale
Mt Hood
National Forest
Gresham
Tualatin
Lake
Oswego
Sandy
Newberg
Oregon City
Canby
Woodburn
Molalla
5
Silverton
Salem
99
Stayton
Lyons
Jefferson
Scio
Albany
Lebanon
Sweet
Home
Brownsville
5
Harrisburg
Santa Clara
Springfield
Eugene
Creswell
Lowell
Cottage
Grove
Oakridge
5
Warm
Springs
Terrebonne
Redmond
Camp at
Deschutes
1-0
1-1
1-2
1-3
1-3
2-1
2-2
2-3
2-4
2-5
Day 1 and 2 Travel
Day 2 Travel to Mouth of Deschutes, afternoon

Day 3- Start at mouth of Deschutes. Travel I-84 to The Dalles, South on 197 to roadcuts, 8 mile then 15 mile road to Petersburg and Fairbanks, Old Moody Road back to Deschutes. Return to The Dalles via 84, south the Trout Creek on 197.

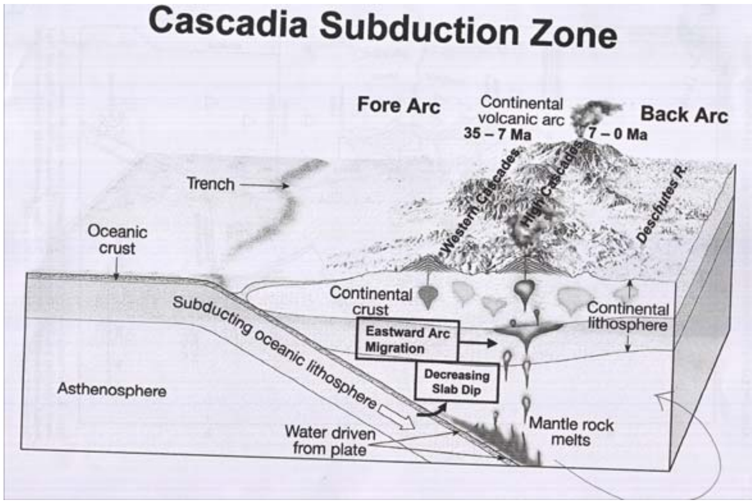


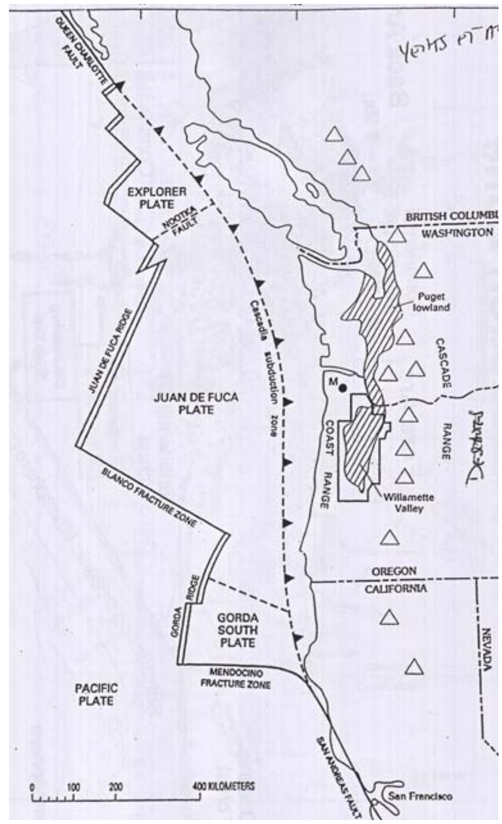
Day 4-6 Travel on the Deschutes by raft.

1-0 Natural Science Building Roof *



The Juan de Fuca plate is an oceanic crustal plate moving to the east, and is subducted under the western moving North American Plate. This is classic subduction tectonics, and the creation of a volcanic arc inland. In Oregon this has resulted in the Oregon Cascades. As the pacific and related plates have moved eastward, and been subducted, ancient exotic formations have also been

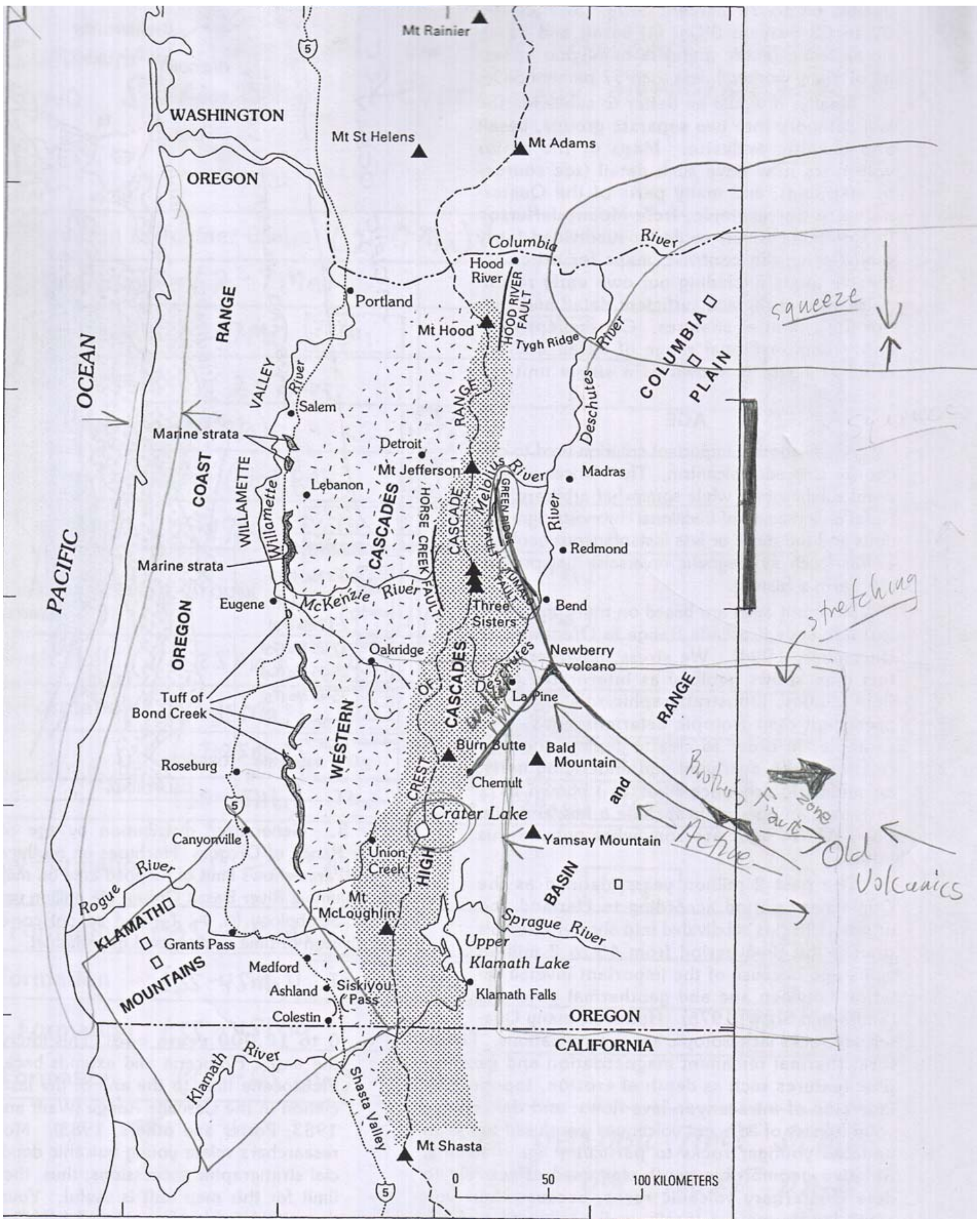




added to the west coast. These exotics have been complex, many of them ancient island chains. The Coast Range of Oregon is a result of some of these accretions, as they are called. The Coastal Range has also been uplifted and folded, which is what has caused this area to be mountainous. Between the Coastal Range and the Cascades, the Willamette Valley has not been uplifted, and over time has been the site of alluvial deposition by the Western Cascades, local basalt flow (emanating from around Boring) and has been the site of deposition by the Missoula Floods. This last series of biblical size flood events, which occurred during the late Pleistocene, deposited hundreds of feet of transported glacial loess, from central and eastern Washington State, as well as glacial erratics from Montana, Idaho and British Columbia (location of glacial Lake Missoula and associated glaciers). The erratics and deposited loess (Willamette Valley Silt) are still evident today. The silts have determined historic and modern use of the valley by humans- mostly agriculture, though today areas are becoming more urban as Oregon begins to feel the effects of overpopulation.

The Columbia River Plateau, part of which is in north-central Oregon and the Columbia Gorge have been the result of the second largest basalt flows known in the world. In Pasco and Yakima, Washington, these series of flows, which occurred from 17 to 6 m.y.a. reached thicknesses of 15,000 feet. They are not as thick on Oregon, but are still very substantial. The High Lava Plains of Central Oregon have also been the site of repeated volcanic flows and eruptions, though the exact cause of these is not perfectly clear. The rest of Oregon- the Blue Mountains, The Klamath Mountains, and the Basin and Range provinces, have all been mostly created by the incredible geothermal energy inside the planet which results in volcanism and volcanically related events. Tectonics is part of the driving force of much of this volcanism. Poorly understood magmatic movements beneath the crust in our area has contributed as well.

Throughout geologic history, Oregon has also been acted upon by hydrological forces- rivers, streams, and lakes. During the Pleistocene, as glaciers advanced and retreated regionally, they too have made their mark upon the northwestern landscape. The entire area has been the site of long term volcanism, punctuated by sudden geologic events such as eruptions and geologic floods. Volcanism, and its interaction with hydrology is a recurring theme, as we shall see, in Oregon geologic history. The interaction of our geology and hydrology is the focus of this course, and on our field trip, we visited a variety of sites that clearly demonstrate this history.



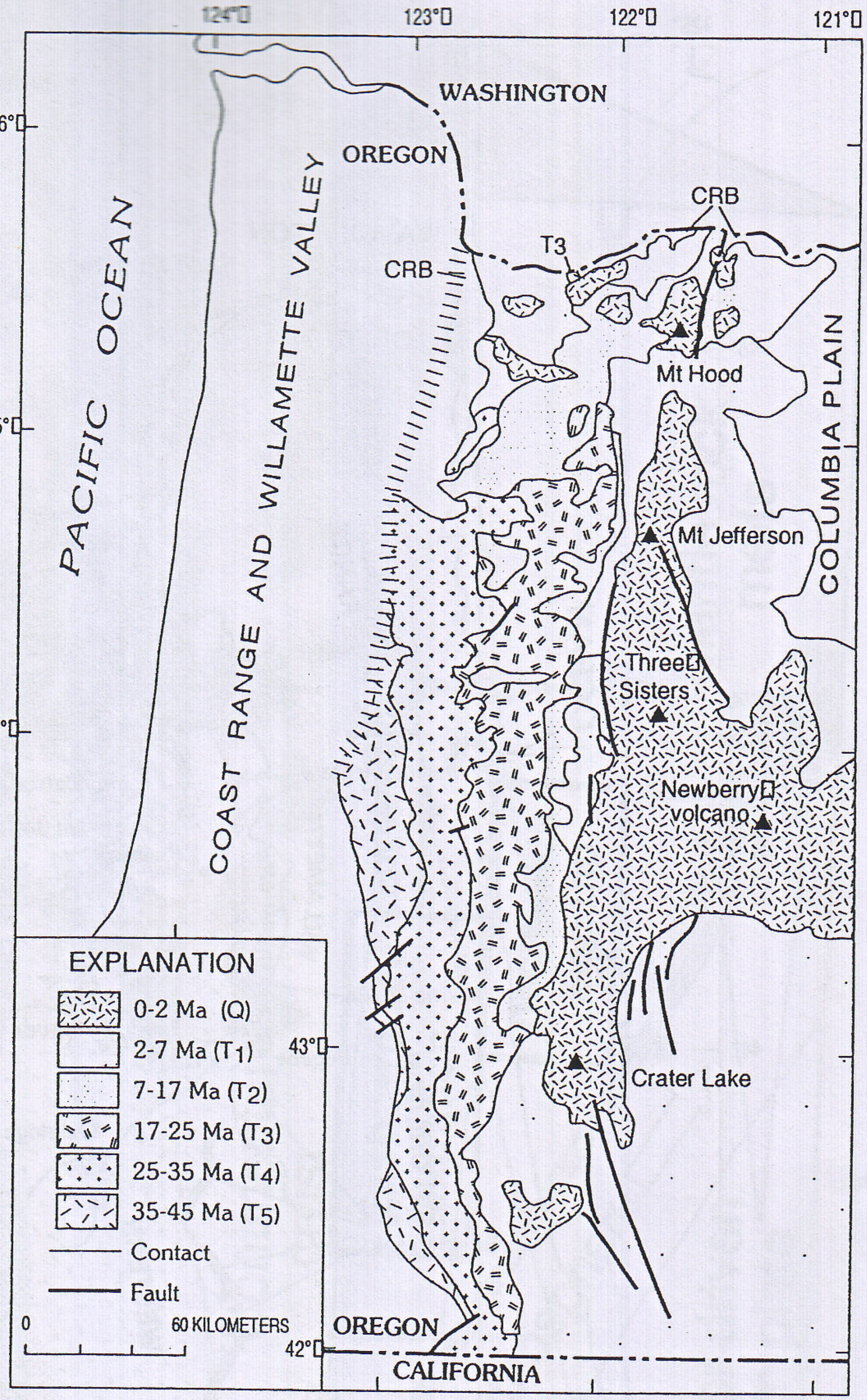
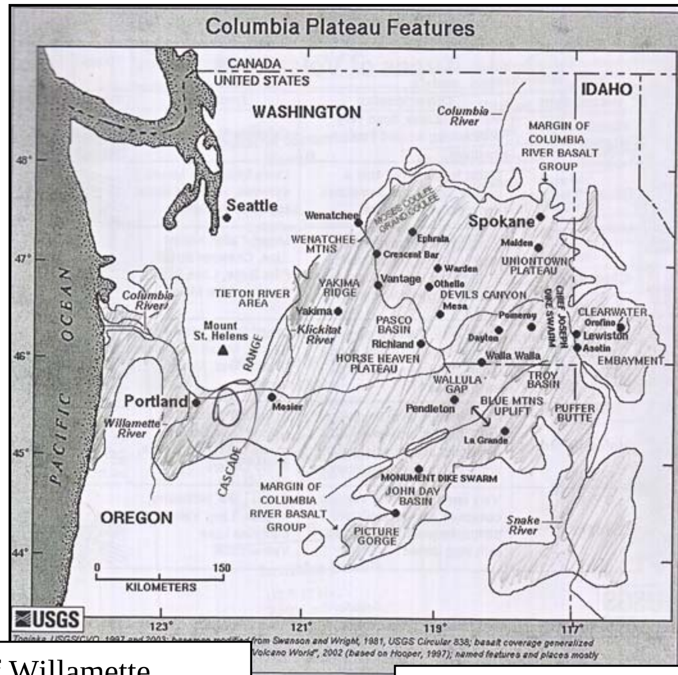


Figure 3. Generalized distribution by age of rock in Cascade Range of Oregon. Hachures on northwest side of patterned area shows limit of mapped area on map sheet 1. CRB, Columbia River Basalt Group; Ma million years before present. Symbology (Q, T_1, T_2, and so on) correspond to broad division of time as discussed in pamphlet.

Locations of Willamette Valley glacial erratics from Missoula floods



Extent of CRBs in the Pacific Northwest

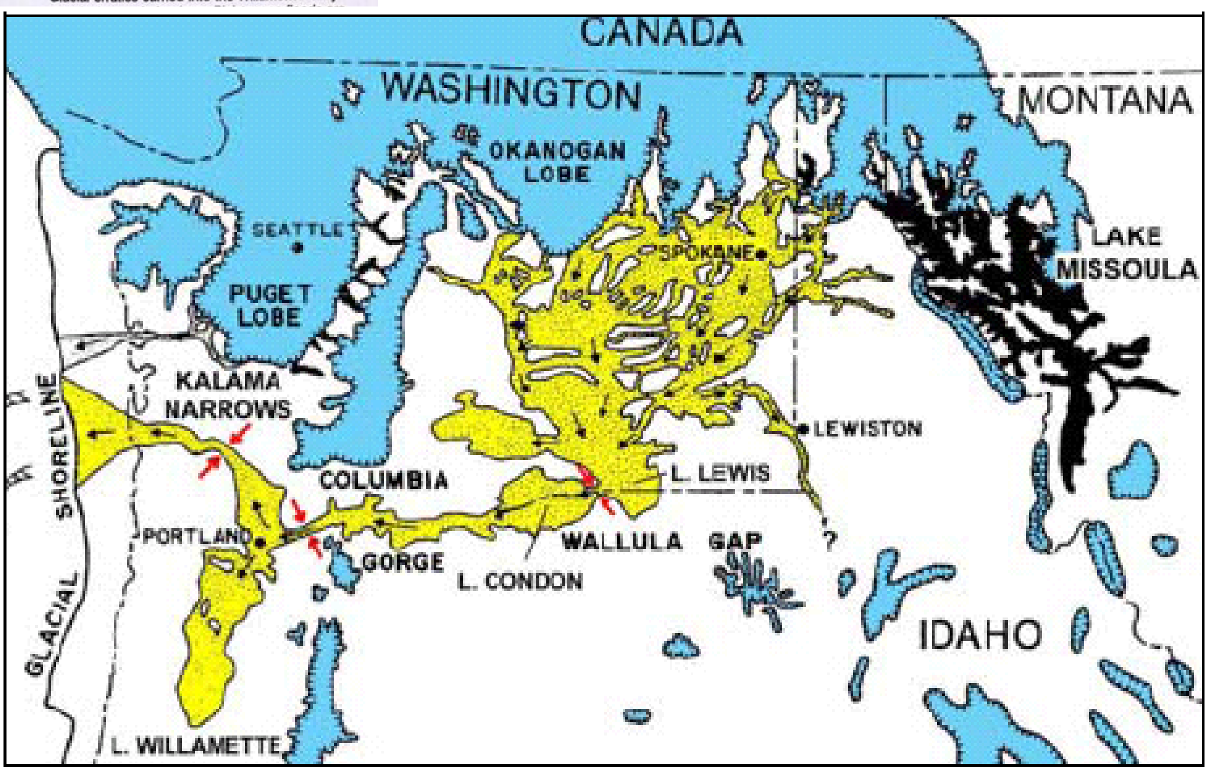
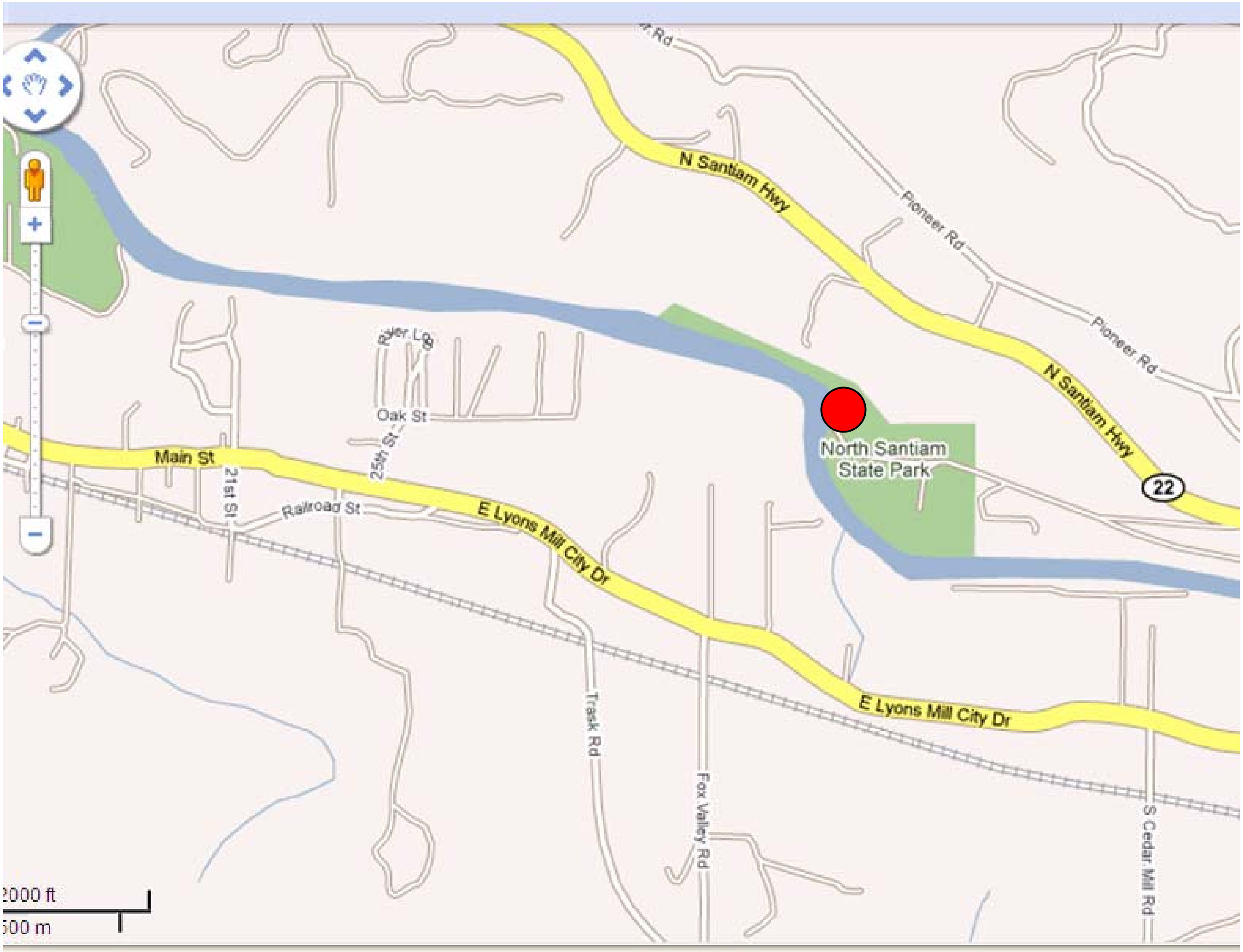


Figure 4—Flood discharge across Idaho, Washington, and Oregon.

Day

Generalized extent of Late Pleistocene Glacial Lake Missoula and the approximately, 100 Missoula floods.

1-1 Santiam River State Park *



At Santiam River State Park we began hands on learning and covered some general concepts about geomorphic interpretation. There are four considerations when you consider a site and its geomorphology- 1.Landform- the shape, and thus name, of what you are looking at; 2. Material- regolith (broken up, softer) vs. lithic (hard, bedrock), soils, fines, cobbles, etc.; 3. Process- what geologic processes happened at your site? Deposition? Erosion? Eruption? Paleosols here? 4. Age- when did these processes happen? How old is parent material? How long did this take?

Rivers do work, that's just straight physics. They are fluid, subject to gravity, and can dissolve (dissolved load) or suspend (suspension load) various size material, even up to large boulders. They are subject to normal and flood levels, and it is at the higher, flood levels that much of the erosive and depositional work is done, because higher amounts of water can dissolve and suspend more material. These flood events are the recurrent theme in Oregon hydrology and paleohydrology.

The gravel and cobble depositions at the park we visited are good examples of meteorological flood processes. The larger cobbles in the river and along the bank are well rounded, imbricated and clear of any fines. Farther up on the flood terrace, where water flowed more slowly as the floods receded, finer gravels and particles were depositied as the water lost force and these materials sorted out. We found other evidence as well- a walking tree, with its roots exposed from flood erosion, an embedded cobble in the tree bark, and we were able to approximately date the latest series of flood events with this information.

1-2 Detroit Dam/Santiam River *

Dams have been periodically, and repeatedly, formed in the Cascades and Central Oregon, as glaciers, lahars, landslides and lava flows plugged streams, creating “knickpoints”. Dams change the qualities of a stream as long as they exist. Deposition occurs in the slow or even still waters of lakes that have a zero slope. Downstream, at the knickpoint, the slope is close to vertical, causing increased erosion there. Typically these dams fail, causing catastrophic geological floods that are instantaneously released. The clues to when these floods occurred, and how they acted, can be found in wider areas of any river valley subjected to these types of events. The discovery and study of these clues and the ancient behavior of rivers is called paleohydrology. The study of the flood events alone is paleoflood history. Paleohydrology is an important tool in understanding how rivers acted, but it is also important in understanding how floods will act in the future, for certainly these types of events will recur in the future as paleohdrological events repeat themselves in a never ending cycle.

We have seen that geologic floods are part and parcel of northwestern paleogeology. But humans have also impacted hydrology here in a big way. During and after the Great Depression, Franklin Roosevelt’s administration encouraged damming of all the major rivers in the northwest for some supportable reasons- mostly having to do with economic development. We enjoy the benefits of these- recreational use of dammed lakes, flood control, reservoirs for agriculture and urban water use, etc. However, the long term ecological effect of these many dams was poorly understood, and many were built in a way that ignored the salmon fisheries that have been a historic part of northwest culture. The result has been a devastating decline in our salmon and salmonid species populations. Many public arguments have been put forth, trying to determine who is to blame and proposing stop-gap solutions to a problem that is complex, given our dependence on the benefits of dams, all the while ignoring the simple fact that the actual cause is simple: dams kill salmon. All of these dams will face the same “problem” that natural dams do- they will eventually fail. As we struggle with the salmon issue and the aging of these dams, and what to to about it, we will have to make some contentious choices in the decades to come.

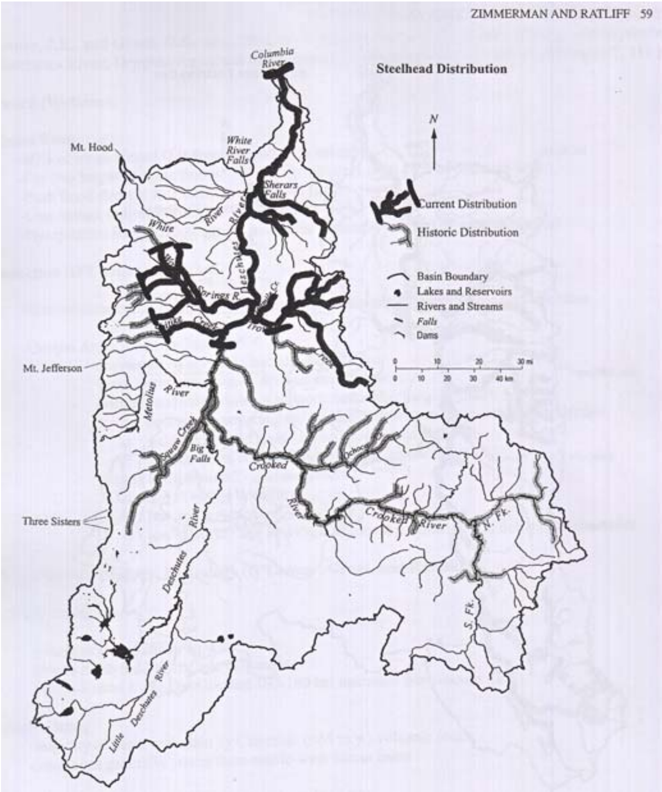


Figure 6. Present and historic distribution of steelhead (*Oncorhynchus mykiss*) in the Deschutes River basin, Oregon.

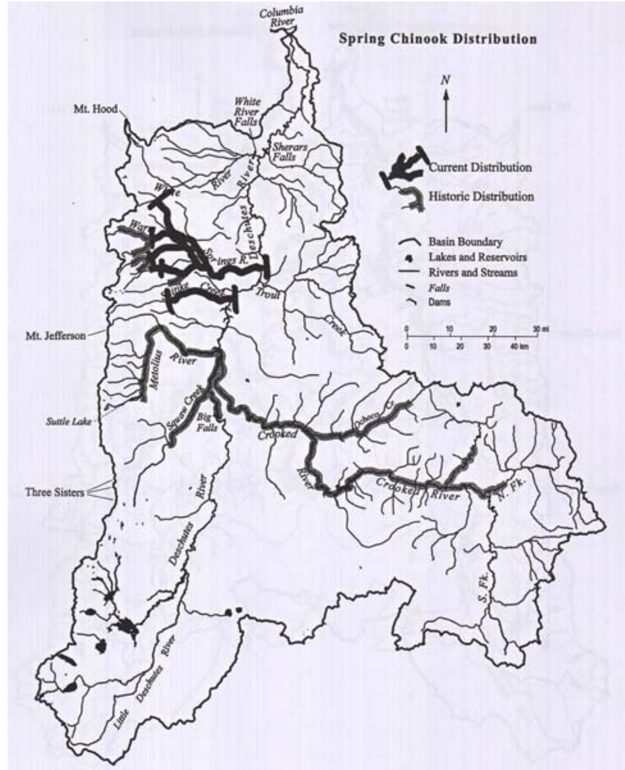
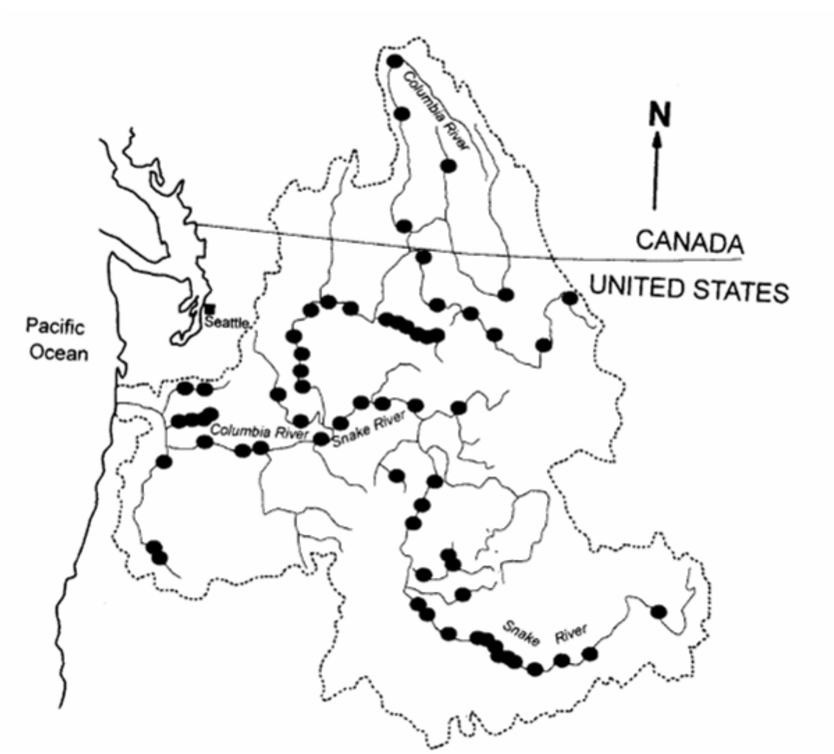


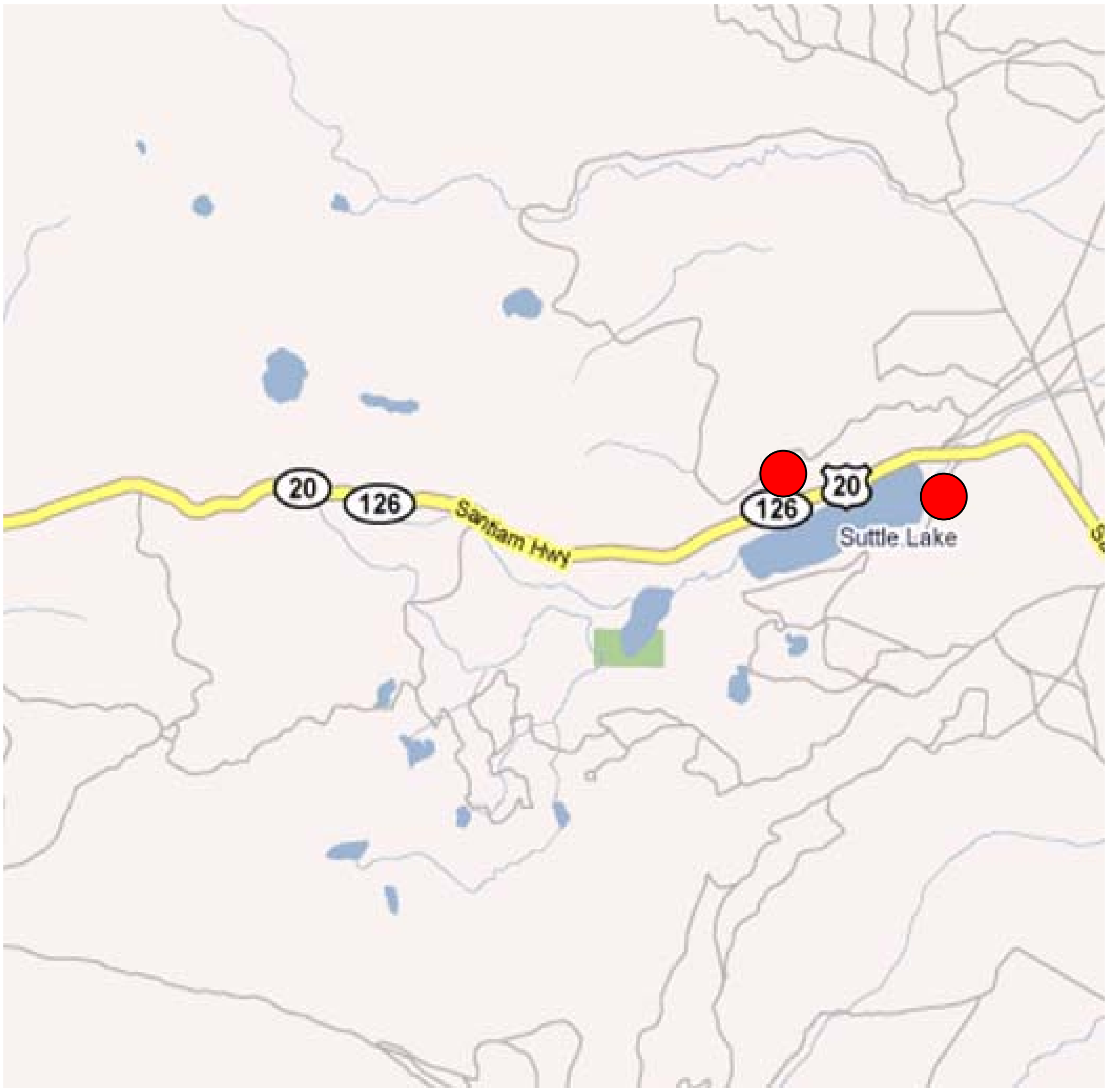
Figure 4. Present and historic distribution of spring chinook salmon (*Oncorhynchus tshawytscha*) in the Deschutes River basin, Oregon.

Two examples of changes in distribution of salmonid species in the Deschutes River Basin as the result of damming.

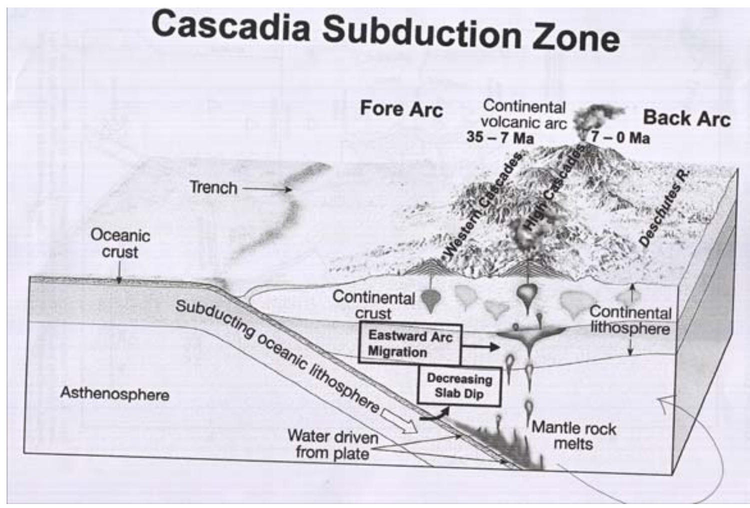


Black dots show location of dams in Columbia River Basin. Is it any wonder we have a problem with salmonid populations?

1-3 Suttle Lake/ Mt. Washington Overview *



On Highway 22, just down from Santiam Pass, we pulled over to the Mt. Washington overview. Here, to the north, just across the highway, we observed diamicton, a mix of different sizes clasts and fines, that were angular, not rounded. This material was on an exposed hillslope- a cutbank created by the highway. This site is the zone of deposition by a Pleistocene glacier that existed here. The "glacial till" we saw is the result of deposition of ground up rock by the glacier, as it flowed slowly downhill, to the east, moving the till from its center to its edge. If this were not a large ridge face, the result would have been a lateral moraine- an elongated, low ridge of glacial till that marks the side zone of deposition by glaciers. As it is, the till was deposited, but the hillside absorbed the deposition without much change in geomorphology, because it is big and steep. We will discuss more about this when we review the visit to Suttle Lake.



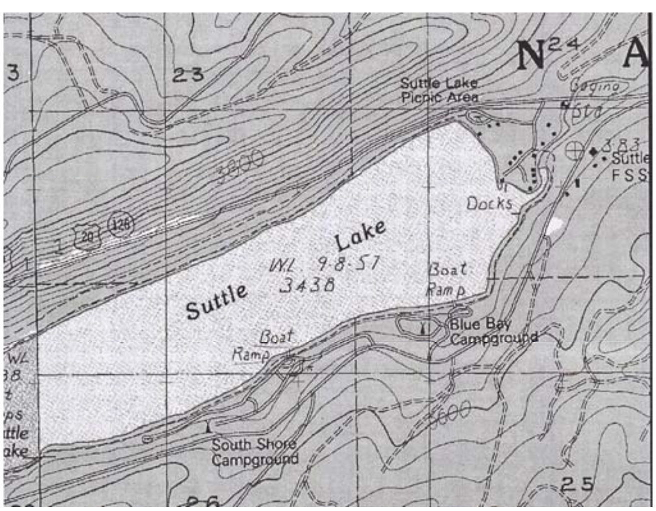
Mt. Washington, to the southwest, and Black Butte, to the east, are both volcanoes. Mt. Washington is actually younger than Black Butte, yet it appears weathered, carved, while Black Butte, which is older, appears almost pristine, a perfect cone. Several important forces caused this. As moisture laden weather systems from the Pacific Ocean move westward across Oregon they dump large amounts of precipitation on the Coast Range. In fact, we have actual rainforests in some locations there. But the Coast Range does not exceed about 5,000 feet, so plenty of moisture is retained in systems that move on to the Cascades. Here, adiabatic cooling results in more precipitation. As the systems move east, and drop back down in elevation, adiabatic warming occurs. Already depleted of most of their moisture, and now warmer, these systems become relatively dry and a

Black Butte, is a perfect cone because it is not weathered by glaciers due to the rainshadow. Mt. Washington, actually younger than Black Butte and a few miles west, is heavily carved by glaciers and looks older because it is not in the rainshadow.

rainshadow effect is created. That's why eastern Oregon is arid. On the east slopes of the High Cascades, enough precipitation is dropped in winter to cause flood events if the temperature rises significantly, but just a few miles further east remains fairly dry (10-20 inches annual rainfall). The rainshadow effect occurred during the Pleistocene, when global climate fluctuations resulted in the cyclical advance and retreat of glaciers, and the northwest was strongly affected during this time. Glaciers formed on Mt. Washington and all over the Cascades, including the upper eastern slopes, but not farther east, because of the rain shadow. So, Black Butte was not glaciated, while Mt. Washington was. The result today is that we see a craggy and worn Mt. Washington because it was eroded by glaciers, while we see a nearly pristine, perfect cone at Black Butte.

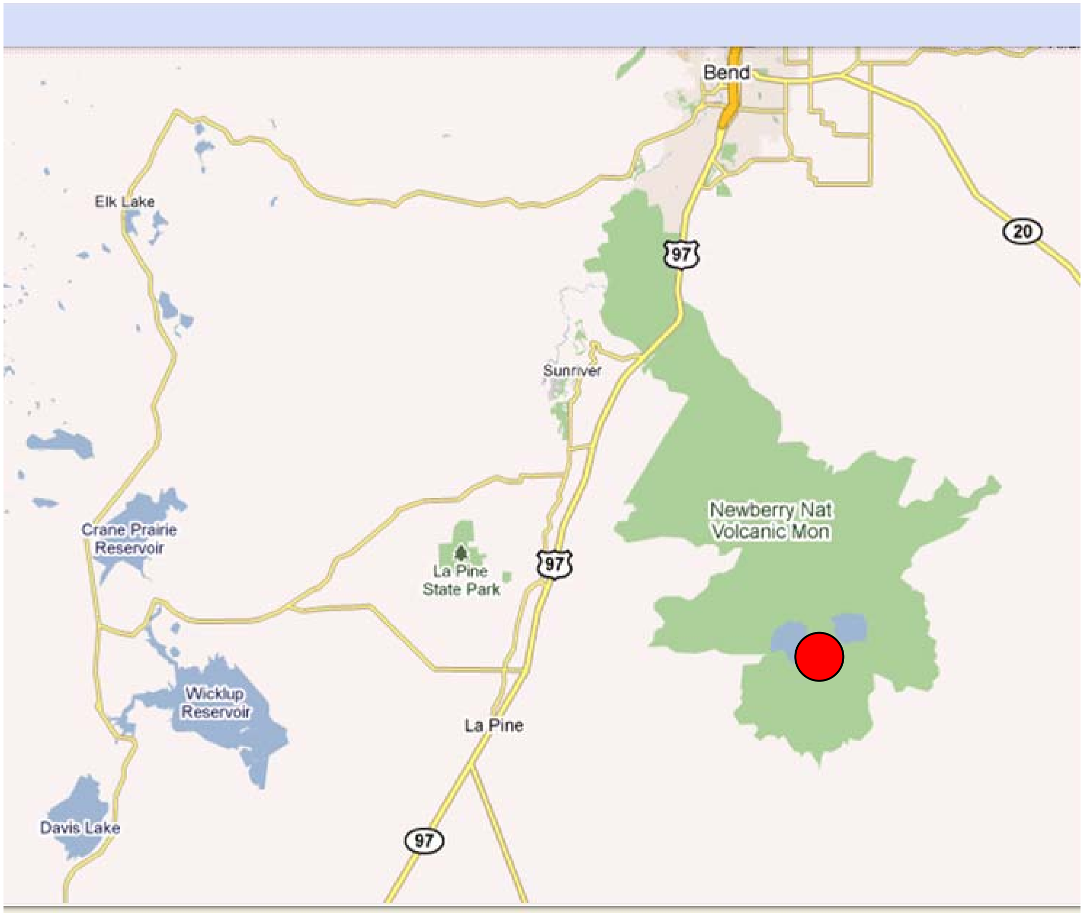
The Cascades actually consist of two volcanic arcs- the older Western Cascades, and the younger High Cascades. This is the result of the shortening of the length of the Juan de Fuca plate as it has subducted over time. In turn, because the plate is shorter, its tendency to move downward at a steep angle has been mitigated and its angle of subduction is now slightly shallower. This has cause the zone of melting to move east (it takes the plate longer, or more distance, to get deep enough to melt). The original, Western cascades still exist today, but are dormant, while the newer High Cascades are still being built today and the High Cascades has plenty of active volcanoes. Mt. Washington is in the High Cascades, although it is not active at this time.

Settle Lake was created by a glacier, under the conditions of the Pleistocene mentioned above. The glaicial till at the Mt. Washington overlook marks the northern edge of the once east flowing glacier. The low ridge in the photo at left is a lateral moraine, to the south, deposited by the same glacier. The student in the lower left of the photo is standing on the eastern terminal moraine, although it has been modified by gravels brought in by humans. This glacier was a cirque, a glacial shape that occurs when a smaller glacier cuts into the face of a ridge, scooping out a shallow to deep bowl that looks tilted due to the slope on the face of the ridge. As a glacier moves, cutting, breaking and grinding the underlying material, it tends to

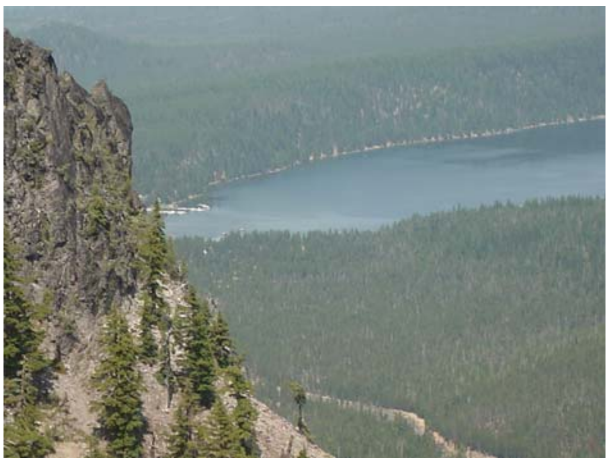


move that material from its center to its edges, creating lateral moraines like the one we see. At the terminus, a glacier deposits the same kind of glacial till. A terminus, or end, of a glacier is the point where melting exceeds ice deposition- its as far downhill as the glacier has gone during some period of its existence. The terminal moraine of the cirque that was here dammed Suttle Lake, which was filled in as the glacier melted. This terminal moraine is a dam that will one day fail, resulting in a geologic flood, if humans do not continue to maintain it. That's the story of all geomorphic dams. This cycle has been repeated throughout all regions of Oregon where glaciation existed. As we shall see, other causes of geomorphic dams, have the same eventual result.

2-1 Paulina Peak / Newberry Caldera *



About 7,000 years ago, Mt. Mazama collapsed on itself, and the collapse generated a massive explosion that left behind the caldera we know as Crater Lake. The explosion generated huge amounts of air born volcanic dust and ash, which moved north and west across Oregon in large amounts, and in lesser amounts across much of the western United States. Newberry Volcano, located close to Lapine State Park, where this photo was taken, also collapsed and formed a caldera, though not quite on the grand scale of Mazama. The ash in this photo was about 5 feet deep, attesting to the huge ashfall from Mazama (about 40-50 miles to the southwest). The Mazama ashflow has been analyzed and dated, so that wherever we find it, we can use it to help date strata above and below it. Similar ash layers are found, not surprisingly, throughout the northwest and are helpful in dating wherever they are found. An eruption of Mt. St. Helens, and the subsequent ashfall helped scientists to pinpoint some of the Missoula Floods that occurred about 13,000 years ago. We looked at Mount Mazama ash on the slopes of Newberry Crater and, as we shall see, used it to interpret ages at the bottom of Paulina Creek near Ogden Camp.

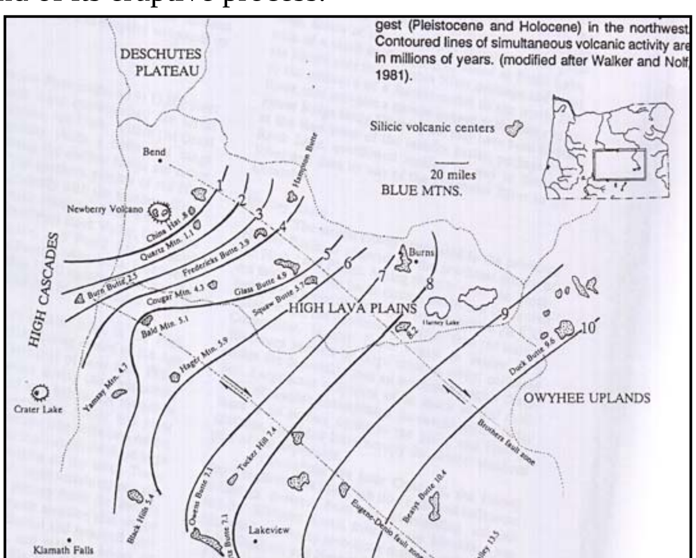


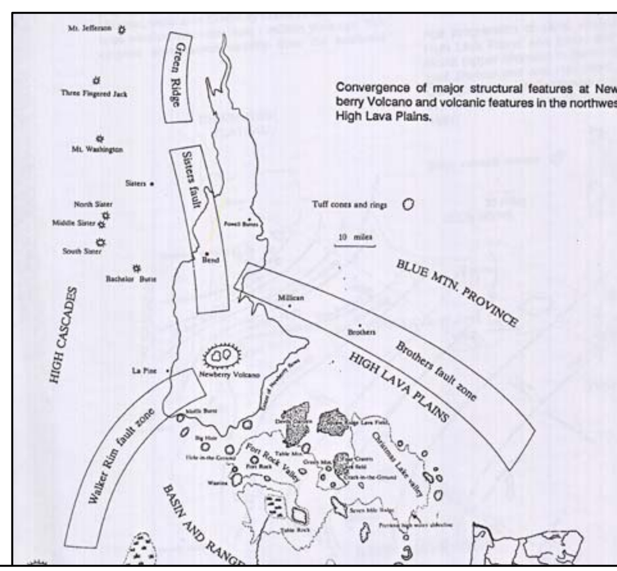
Paulina Peak is the remnant of the upper flanks of Newberry volcano, which began formation and eruptions about half a million years ago. Newberry is a low profile, composite, shield volcano. It is located on the High Lava Plains of central Oregon. The High Lava Plains are entirely volcanic, but have a different origin than the Cascades Volcanic Arc. The events have been highly complex, and the underlying forces are not completely understood, but they can be summarized as follows: For at least the last 10 million years, the High Lava Plains, a roughly rectangular area east of the High Cascades and south of the Columbia River Plateau, bounded on the west by the Blue Mountains and to the south by the Basin and Range province, has been stretched and twisted in a clockwise fashion. This area has 3 fault systems that intersect, with Newberry Volcano located smack in the middle of all of them. The faulting and cracks in this area have allowed numerous venting of mostly basaltic lava flows to cover the underlying strata. The original sources of these flows were to the south and east of Newberry. They began to flow about 10 million years ago. The origin point of these flows has moved steadily northwest, until it reached, and formed Newberry Volcano about half a million years ago. As recently as 1300 years ago, Newberry was the site of an obsidian flow, within the Caldera.

Newberry has not acted alone. The faults and cracks around it have given rise to flows, even while the volcano itself was erupting and being built (and rebuilt, as we shall see). Starting about 8 miles south of Bend, the volcano stretches for about 35 miles to the south, and is about 12 to 15 miles wide from east to west. Flows from the volcano and related faults and cracks cover the plains around and to the south of Redmond and all the area between there and Bend. The flos extend in large areas about 5 miles to the north of Redmond, while flows that continued down the Crooked and Deschutes rivers reach as far north as Madras. Both rivers were dammed by these flows. Geologic damming of the Deschutes by volcanic activity, as well as landslides, and the failure of these dams is a continually repeated scenario in the geologic and hydrologic history of the river. Nearby Lava Butte, as we shall see, was at least part of the source of a significant flow about 6000 years ago.

Newberry Volcano has formed several times. Earlier in its history, its magma chamber became plugged and empty. Nearby faults and cracks allowed magma to form "parasitic" cinder cones in the area. There are a large number of these, and they can be seen especially well to the south, as shown in the photo. This is a typical sequence seen before a volcano with an empty magma chamber collapses on itself, exploding and creating a caldera, like the one discussed at Crater Lake. Studies are ongoing, to determine the character and age of the cones. So far Dr. Taylor has determined some interesting information about these cones: they can be roughly aged by their currentl shape. Those with a more perfect, classic cone shape, with the crater still evident on top, are younger, while those with the crater filled in, and a less classic cone shape are older. They seem to be associated with faults and cracks in the area, as one would expect, but the evidence is not all in, and Taylor and others are working to complete the picture.

Newberry has exploded and created a caldera at least twice. Currently Paulina and East Lake occupy much of the caldera, separated by flows and volcanic debris deposition that occurred after the last caldera was formed. Interestingly, scientists have discovered evidence of bimodal eruptions at Newberry. Older eruptions and flows were more basaltic (lower in silica, thus less viscous), while more recent flows, such as the obsidian flow 1300 years ago, have been higher in silica, a progression that indicates that Newberry is at the end of its eruptive process.





Progression (left) of volcanism to the northwest in the High Lava Plains, culminating most recently in (right) Newberry Crater and related flows at the junction of Brothers Fault system and two other fault systems.

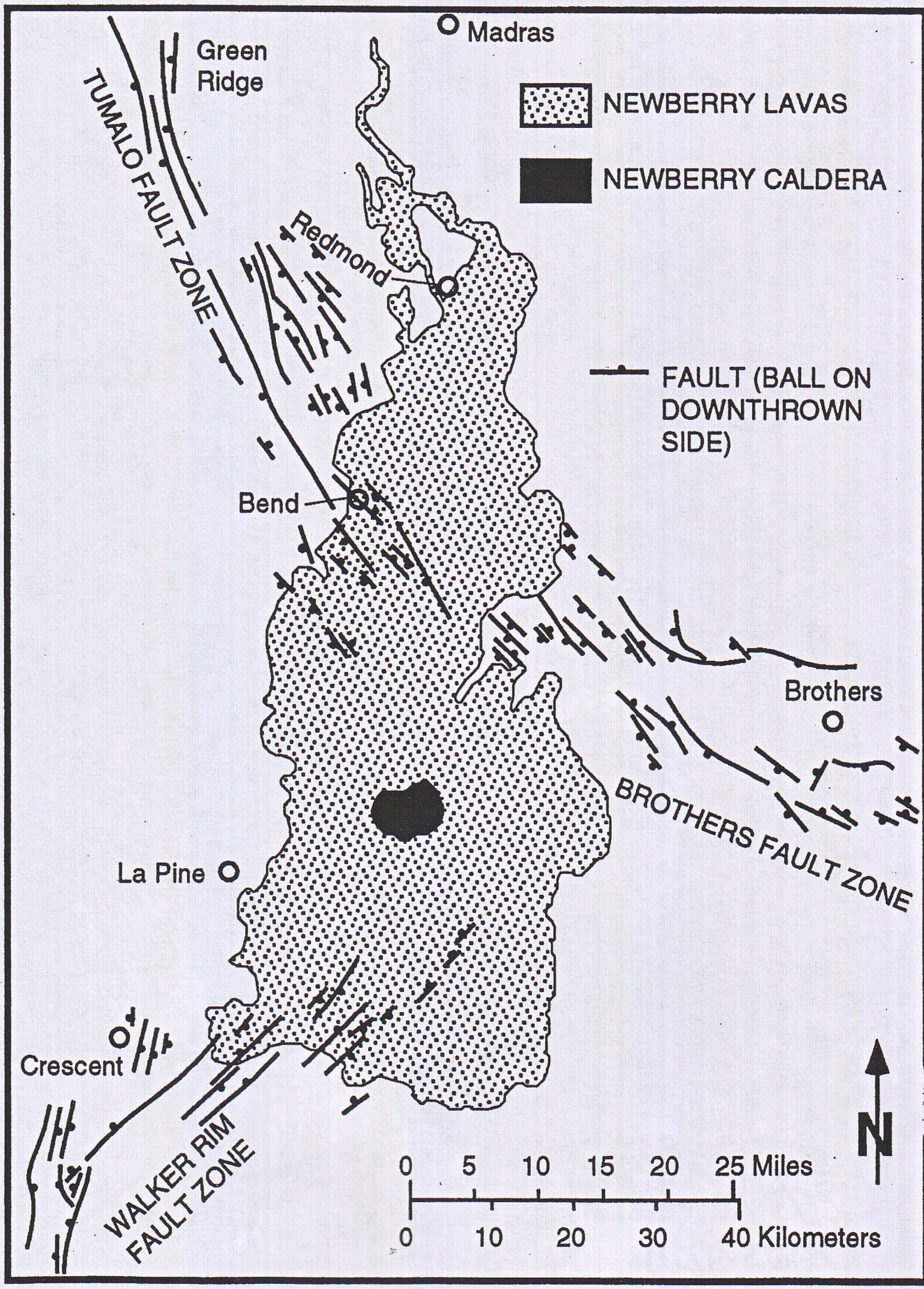


Figure 6 -- Extent of lavas from Newberry Volcano.

Low Profile- shield

collapsed Caldera

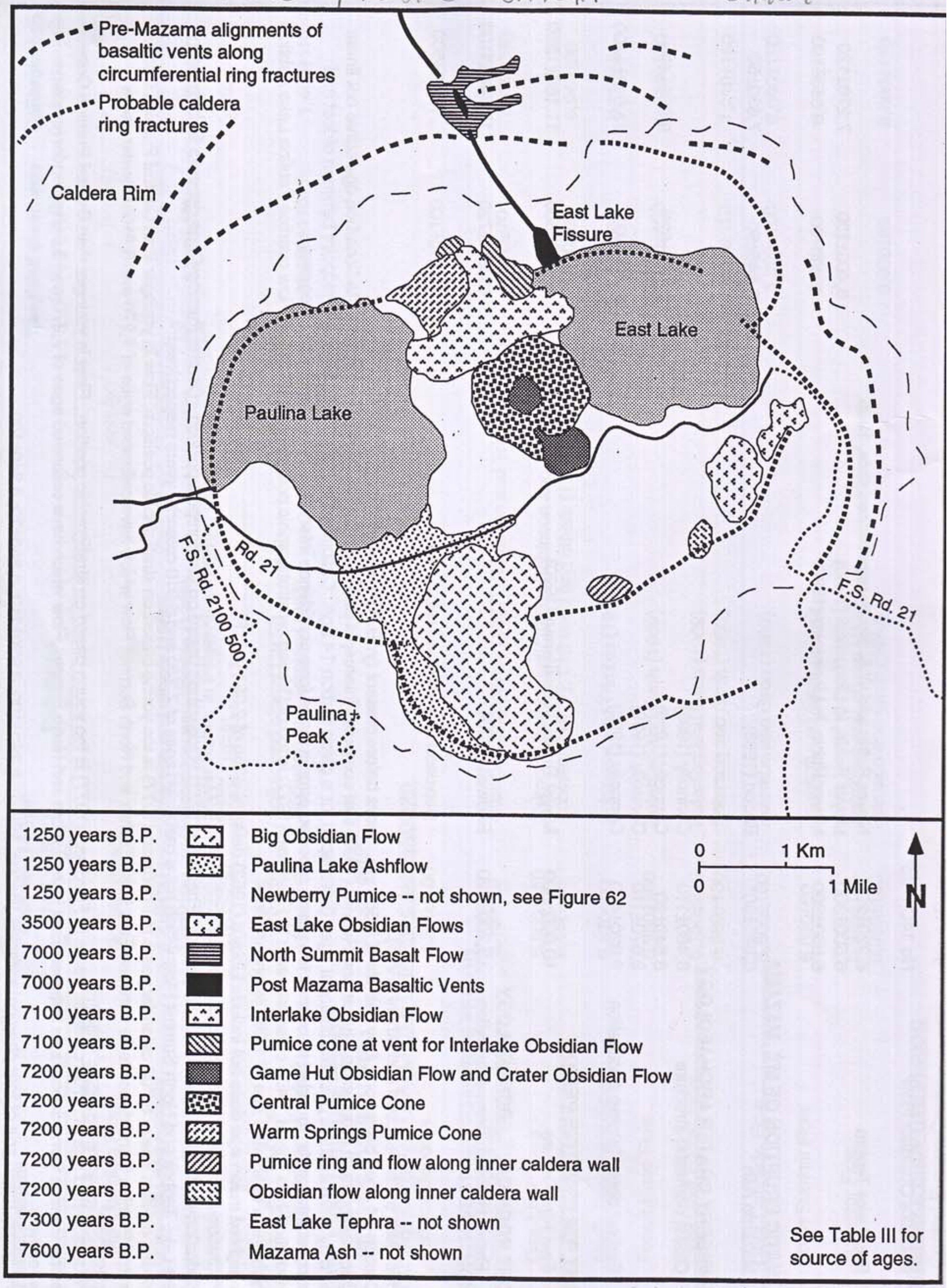


Figure 68 -- Post-Mazama volcanism in Newberry Caldera.

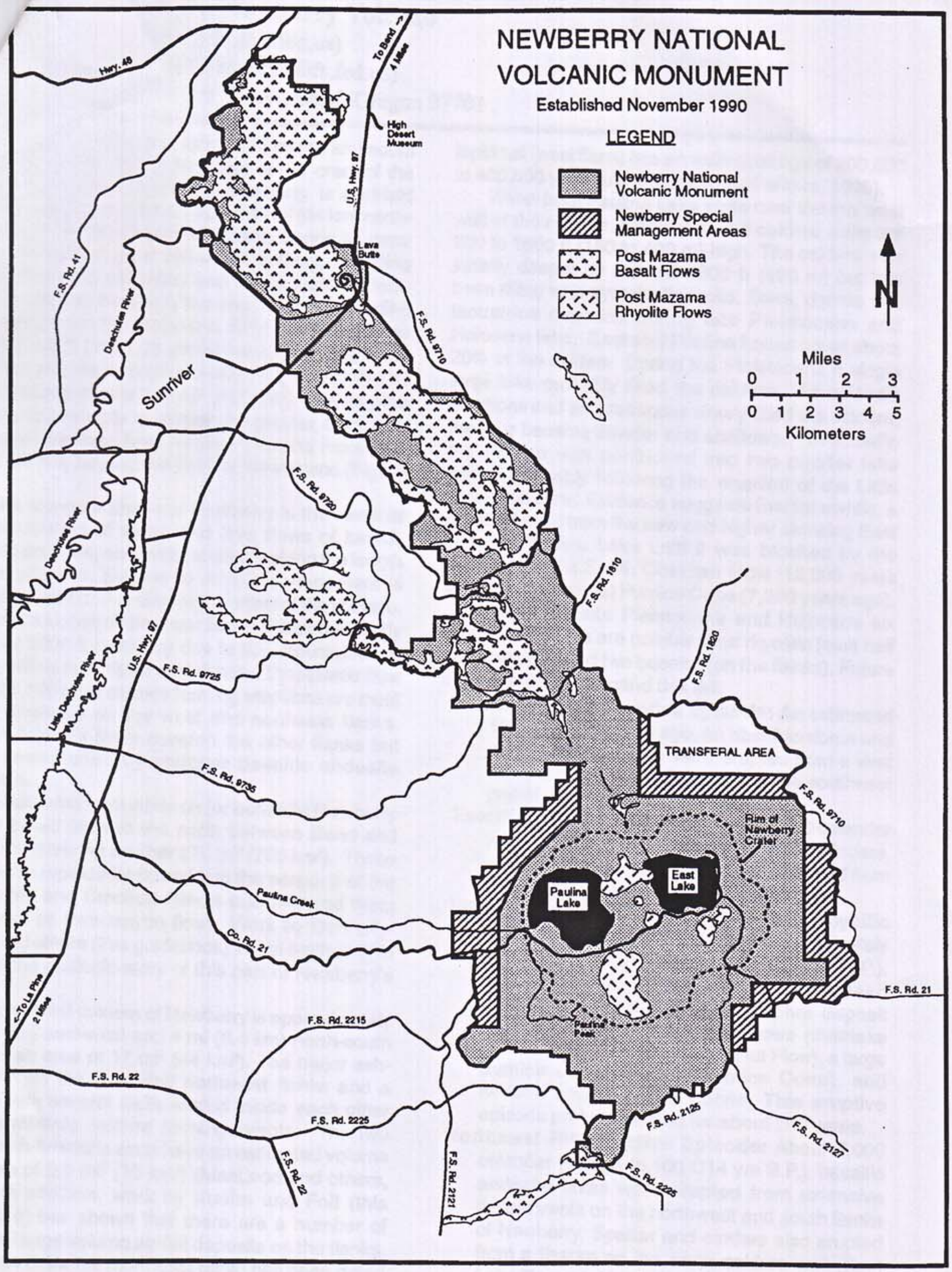
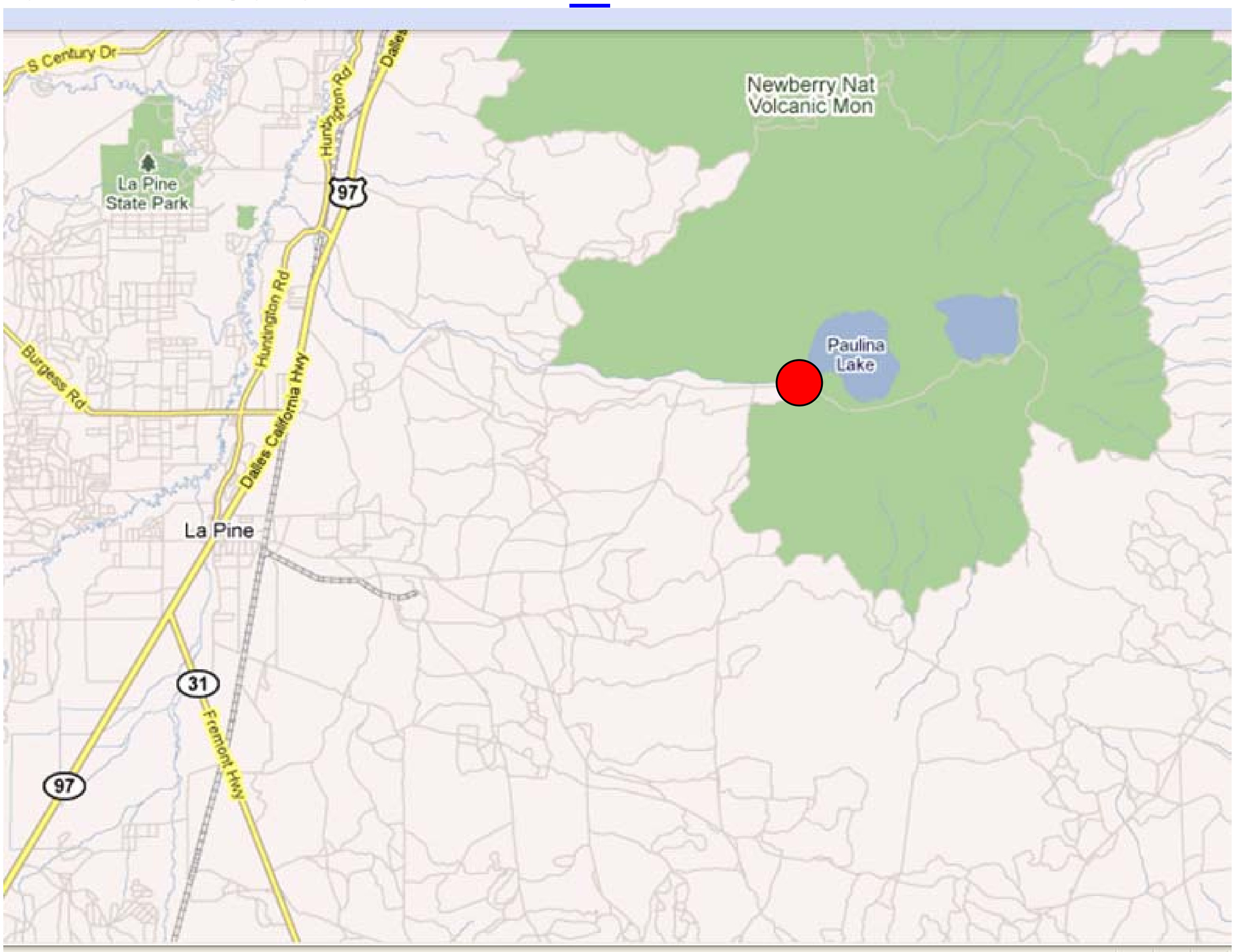


Figure 3. Newberry National Volcanic Monument.

Note the rhyolitic flows, located in the crater proper, which indicate Newberry is probably at the end of its eruptive cycle.

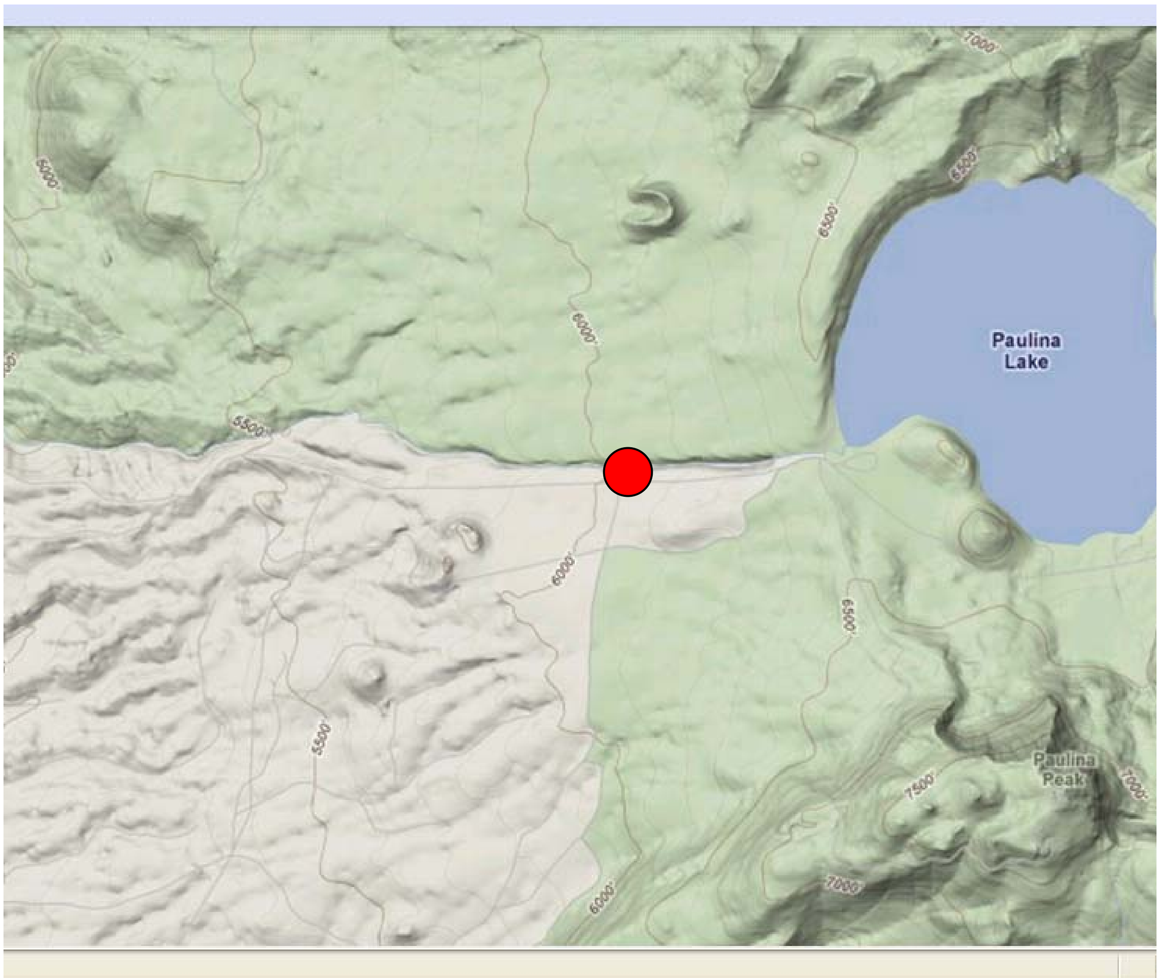
2-2 Paulina Lake Outlet **



At the outlet of Paulina Lake, Paulina Creek flows over a section of bedrock, an old volcanic flow, and then drops vertically for a few feet, into a well developed, rocky channel that shows signs of powerful erosive forces. This drop is a knickpoint, where the stream continually erodes toward its source, eventually causing eventual failure of the dam (in this case the dam is the remnant of the caldera rim), a geologic flood as part or all of the lake empties, and creation of a new knickpoint farther upstream. Again, we see evidence of another example of the violent geologic history of this region of the United States, and Oregon in particular.

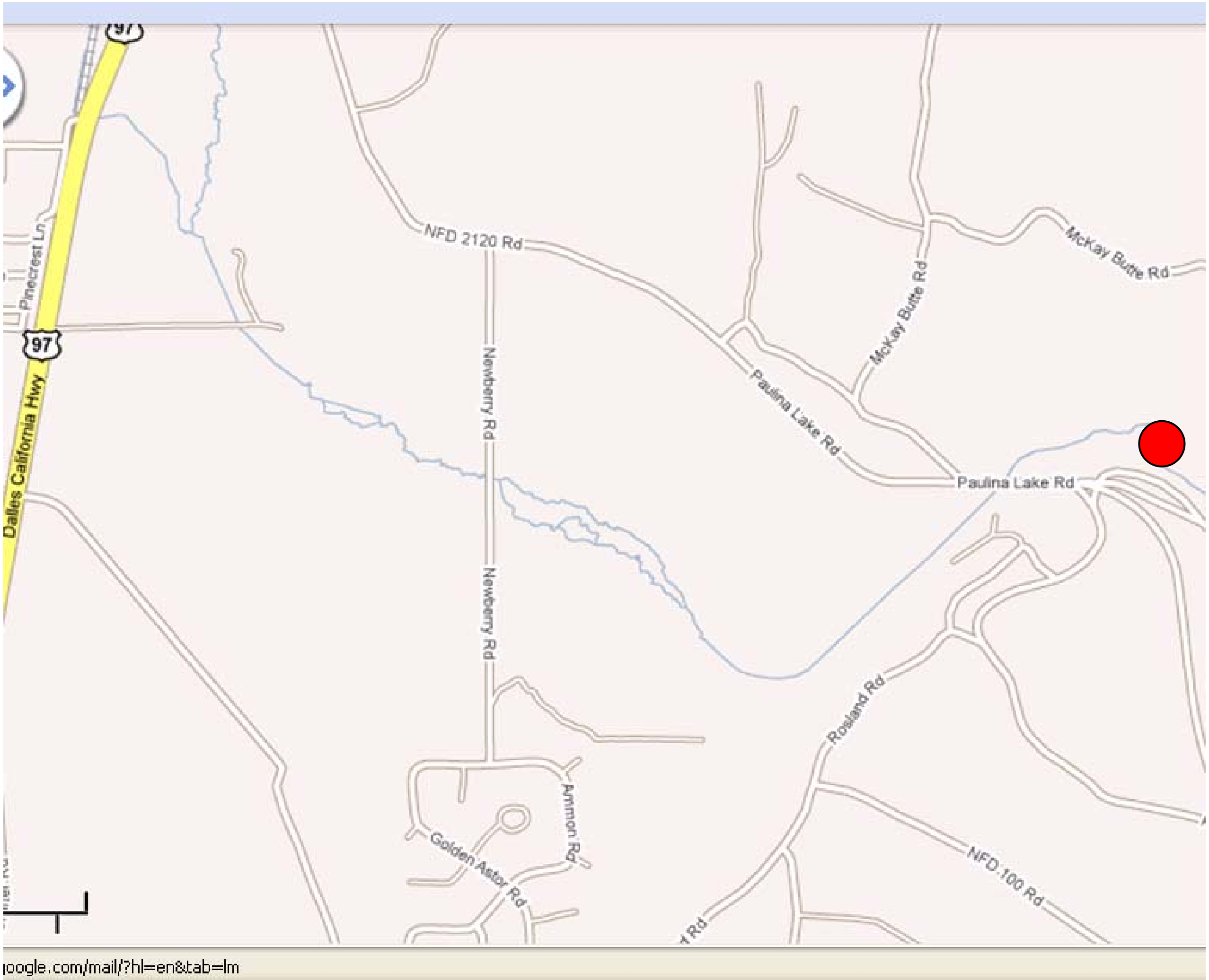
This end of Paulina Lake has been sinking in recent years. The opposite shore is about 2 meters high, and reflects the raising of that end of the lake due to underlying volcanic activity. At that end, wave erosion has undercut the bank, causing parts of it to collapse.

2-3 **Paulina Falls Knickpoint** **



Paulina falls, another knickpoint on Paulina creek, showing vertical drop, and also undercutting of volcanic bedrock, which will lead to failure of the rock, and migration upstream of the knickpoint, also referred to as headward erosion. The interpretive signs located here seem misleading, indicating all of this headward erosion happened in one single event, which is unlikely, although there probably was a catatstrophic event here. Note the undercutting of the bedrock where the falls strikes the surface. This is a typical feature of waterfalls.

2-4 Paulina Creek / Ogden group camp / Paulina Creek Terrace / Catostrophic Flood Record **



Paulina creek drops steeply away from Paulina lake, high up on Newberry Crater. Farther away, as the slopes become much gentler, the creek slows its pace, and the result is deposition of gravels and fines from flood events. Here we see the example of damming, erosion below the dam, and then deposition in a wider, flatter area below the zone of erosion. If this creek were always flowing at the low level shown in the photo, likely the hummocky gravels in the background would not be here. They require flood water to carry them here, they are too heavy and large to dissolve or be easily suspended. This is evidence that either a large meteorological flood or a geological flood from failure of a knickpoint near the lake occurred. We were able to roughly date this flood as having happened in the last 7,000 years because the Mazama ash found just upslope, on a terrace about 40 feet higher than this creek bottom, is not found in the drainage channel. It has been washed away. The terrace elevation, with Mazama ash intact, is evidence of the size of the flood, as are the gravel hummocks. We can make estimates of the flood size by reconstructing channel volume, based on where the ash is present, and where it has washed away. A lower terrace, with no ash, is indication that other floods made deposition here, and the creek has eroded below the intermediate terrace since then.

A scar on the upstream side of this pine tree indicates a flood during the lifetime of this tree, dating that flood to sometime in the last 50 years or so. The rounded cobbles in the photo above, right, were found on the upper terrace, evidence it was indeed a terrace, while the Mazama ash surrounding the pebbles show the terrace was created more than about 7,000 years ago.

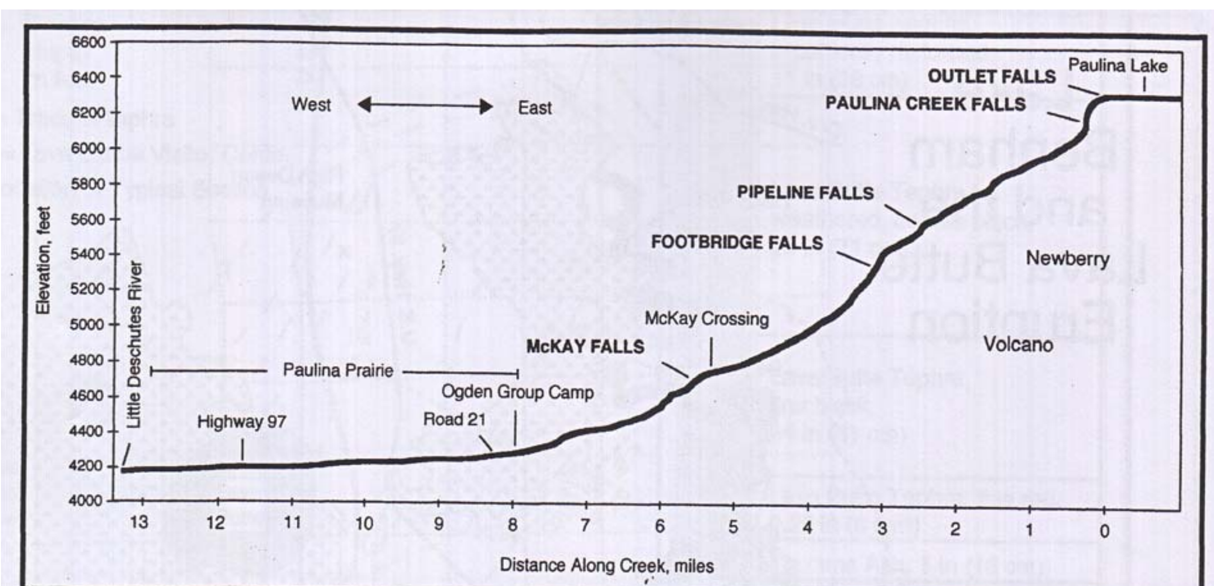
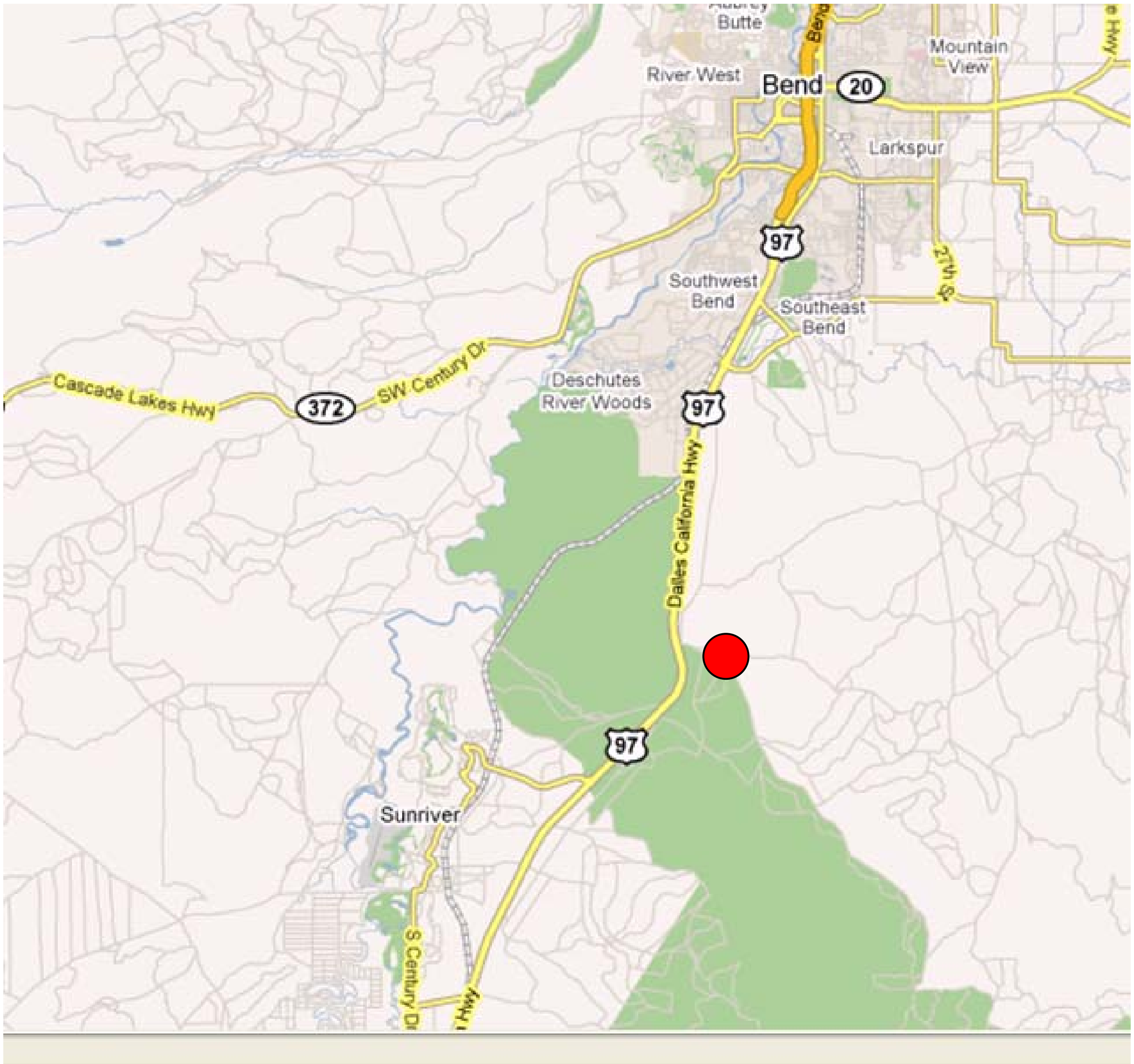


Figure 2. Profile of Paulina Creek showing waterfalls and other features.

2-5 Lava Butte / Lake Benham **



As we have seen, Newberry crater is the largest single physical feature in a series of related volcanic features in the High Lava Plain province. Lava Butte cinder cone is one of the related features. It was “parasitic” to Newberry. Lava Butte is only a few miles north and slightly west of Newberry. Lava butte erupted about 6,000 years ago (dated partially by using small deposits of mazama ash, and a carbon date from a piece of wood that was not completely destroyed when the lava flow here cuased the trees in the local forest to burn). Interestingly, not far from this area, some trees were encased in lava, and casts were formed, that remained hollow after the trees inside burned up. This created a lava cast forest that is part of the overall Newberry National Volcanic Monument. When lava butte and related flows occurred, a tongue of lava reached the Deschutes, once again damming our favorite river. Ancient Lake Benham was formed to the south of the lava tongue, and lacustrine deposits can be found where this lake once existed, allowing us to plot the extent of the lake. The Deschutes eventually eroded the lava tongue, resulting in yet another geologic flood. The location where the river cut through the tongue is currently a knickpoint- Benham falls. It too will eventually erode upsteam.

Newberry and other, smaller cones in the province emit bimodal lava. This means that their silica content changes as magma that once emanated from deep within the earth’s crust gradually begins to emanate from a shallower region. Lavas with low silica content are less viscous, and flow readily. They form basalt when they cool and crystallize into bedrock. Andesitic lavas are intermediate in silica, and rhyolitic extrusions are higher yet. Lavas that are highest in silica cool to form obsidian. So, as these areas have aged, their eruptions have become higher and higher in silica, meaning they formed more vertical cones, rather than low profile basalt flows. Other factors come into play, such as rate of cooling. Lava butte obviously gave rise to basaltic flows- it and nearby vents formed the lava tongue that caused Lake Benham to form, but the cinder cone was formed as the silica content was reduced, and the lava or magma became thicker.

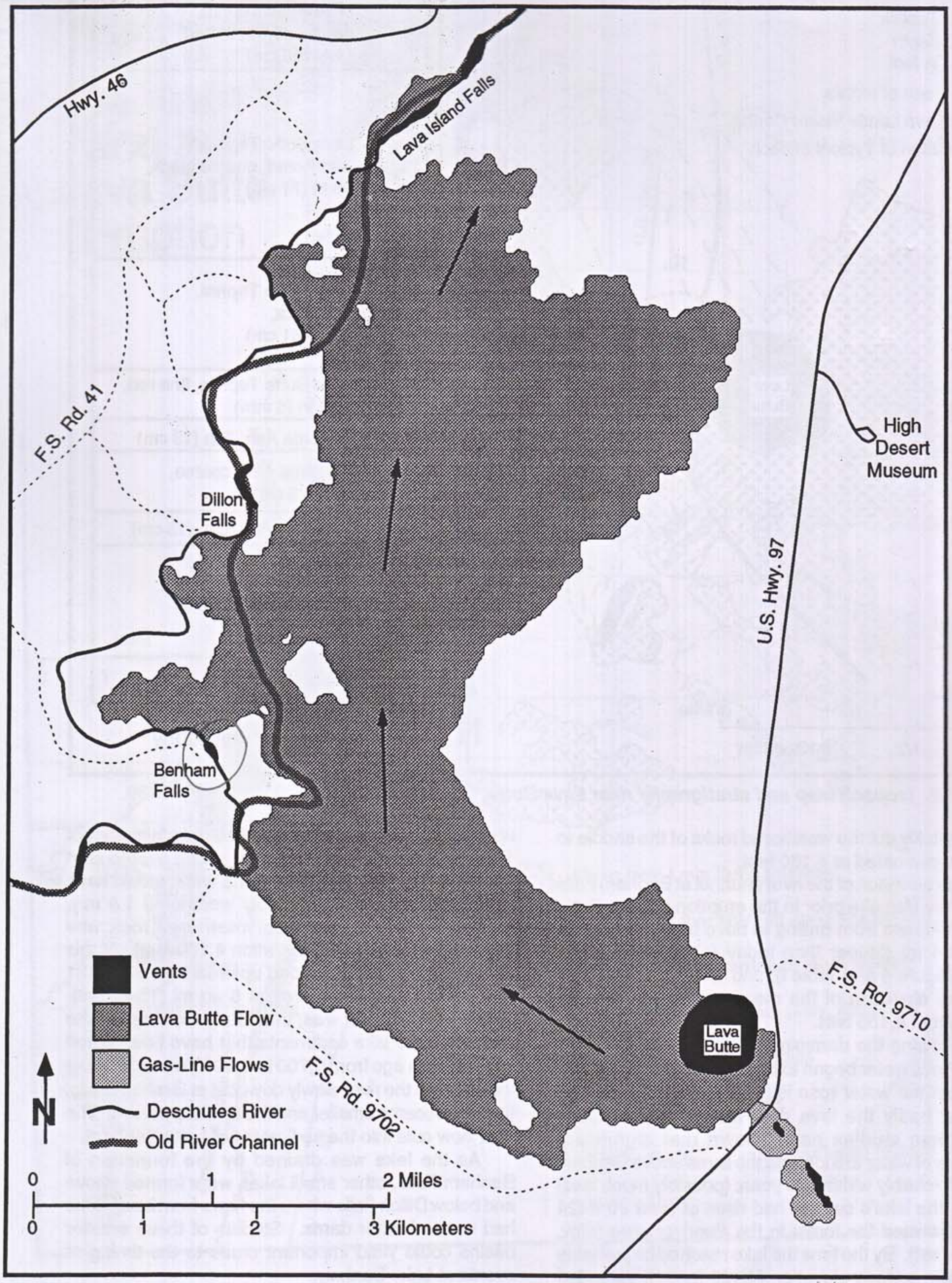


Figure 1. Lava Butte and Gas-Line Flows

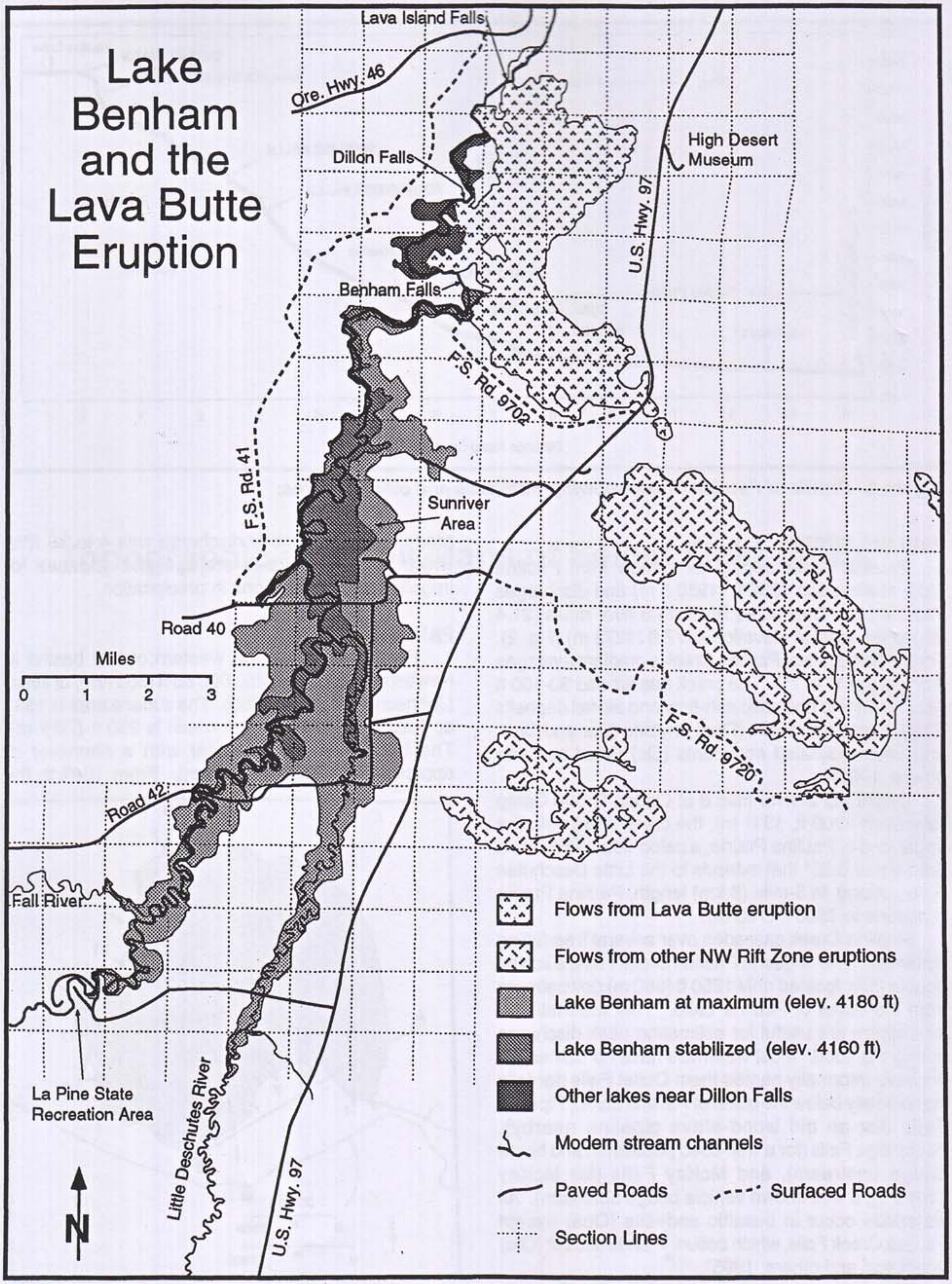


Figure 3. Lake Benham

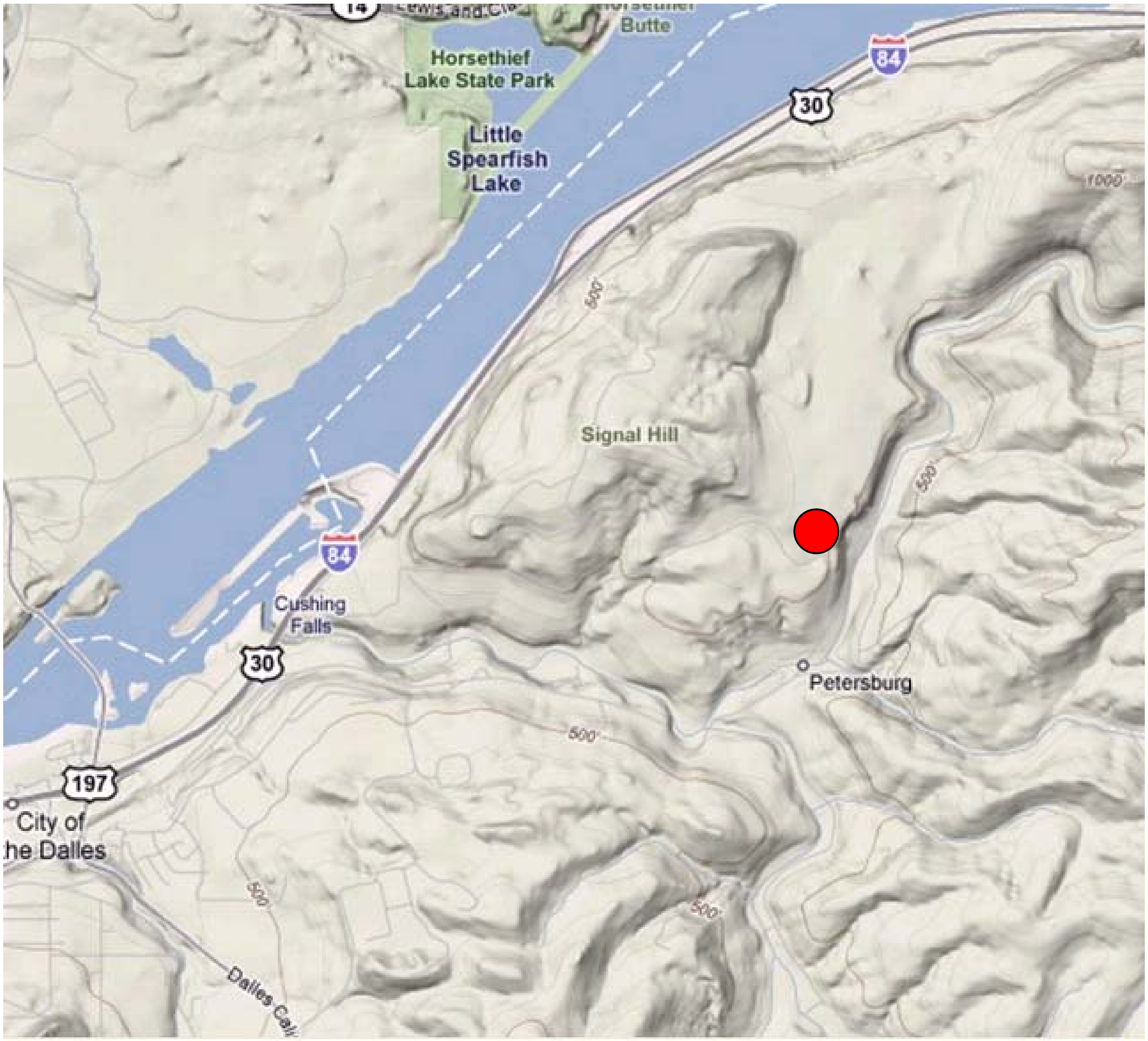
3-1 The Dalles Highway 197 Roadcuts **

We have discussed many times the extent of the CRBs in the Pacific Northwest, and there is no better place to see them than in the Columbia Gorge, which we'll discuss in the next stop on day 3. The Missoula floods occurred about 100 times over a several thousand year period in the very late Pleistocene. The location of the floods are intimately tied to the location of the CRBs, because as we have seen, the extent of the CRBs caused a downdrop of the whole plateau from the sheer weight of all that basalt, ensuring the Columbia River would stay pretty much, though not exactly, where it always was. When Glacial Lake Missoula broke through the ice dam at the east end of what is now Lake Pend Oreille, it followed the CRBs because they provided a downhill course to the mouth of the Columbia River via the Columbia Gorge, albeit the track was a long one. Some floods were larger than others and they may have ranged from about 1,000,000 m^3/s to as large as 10,000,000 m^3/s. All of the floods created hydraulics that broke the rules of normal size physics. The larger floods overwhelmed the Columbia Gorge and spilled over its sidewalls in places, while in other areas the flood waters moved up into tributaries like the Deschutes River. Missoula flood deposits are found up to 45 miles above the mouth of the Deschutes, as far as Maupin.

Highway 197 follows Three Mile Creek a small tributary that flows directly into the Columbia. We traveled up 197 and made several stops along road cuts here, within several miles of the Columbia. Obviously flood waters would have reached here. At our first stop, we examined loess like deposits that were located in a depression between outcrops of what were probably Dalles formation bedrock. This area is within striking distance for wind blown loess from the Okanogan lobe of the Cordilleran ice sheet to the north. So these deposits could have been blown here, and settled into the depression as a result of local wind turbulence patterns. They could also have possibly been placed here by receding Missoula flood waters, which would likely have dumped sediment load as they slowed during recession.

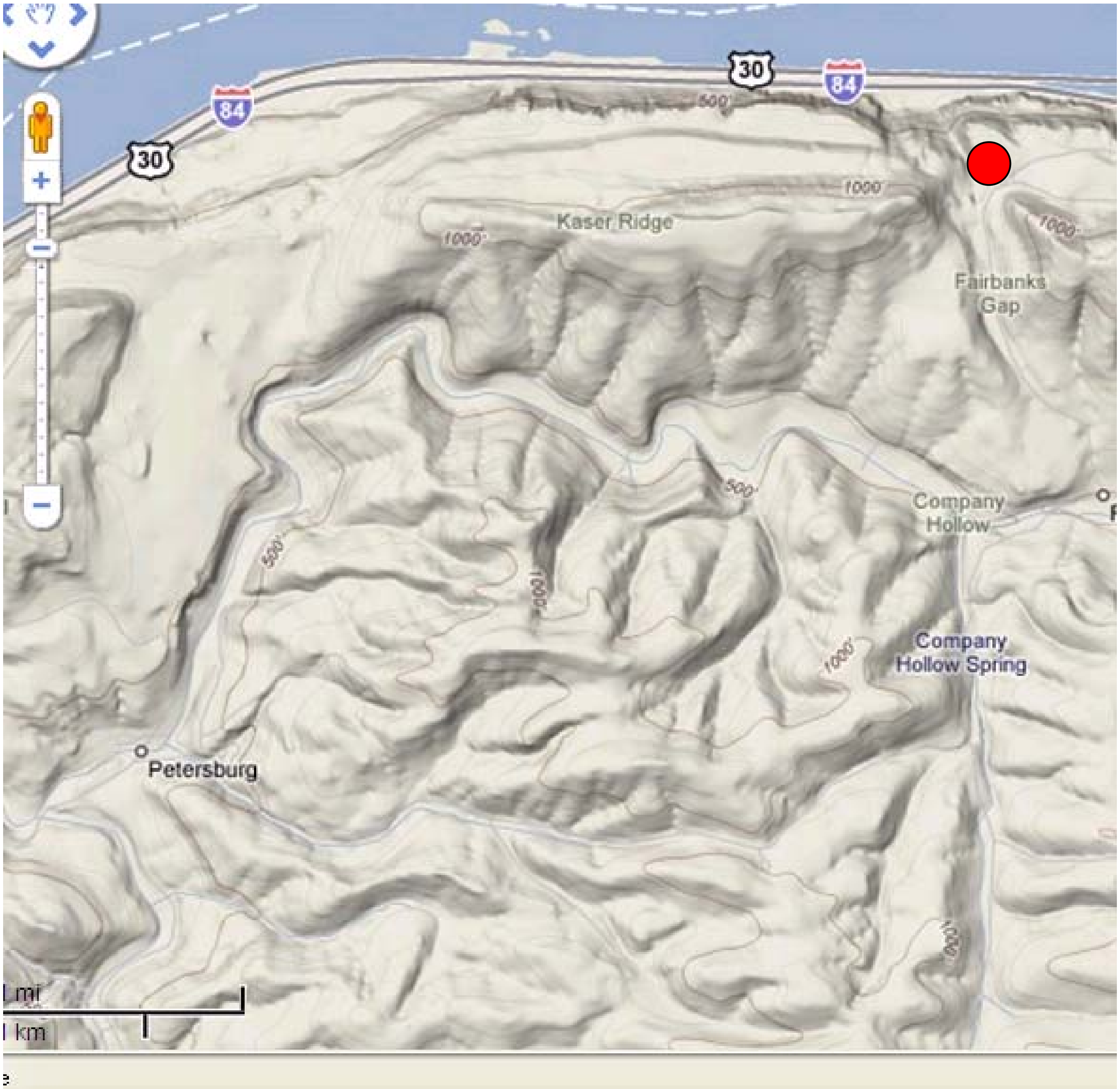
As we moved to the next several roadcuts to the south, we encountered what were probably The Dalles formation. Here we found multiple types of rock of volcanic origin of a variety of types- tuffaceous, ancient lahars, ash, volcanoclastic deposits, and pyroclastic flows. The layers we examined indicated events you see surrounding volcanic eruptions, and Mount hood is only about 35 miles to the west of here. The diamicton we saw probably came from a lahar. Tuffaceous material came from pyroclastic flows. The stratigraphy was quite easy to see. Several layers were punctuated by aridisols, indicating that they were exposed in the neighborhood of tens of thousands of years and that while those soils, now paleosols, above the aridisols developed, obviously the climate was arid.

3-2 Petersburg Bar Flood Delta **

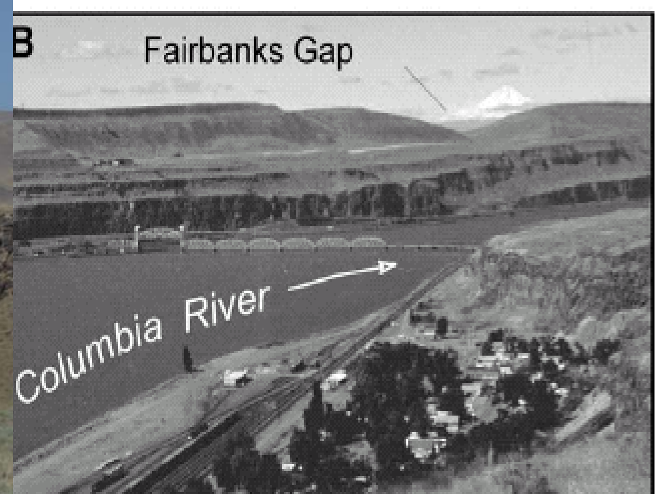


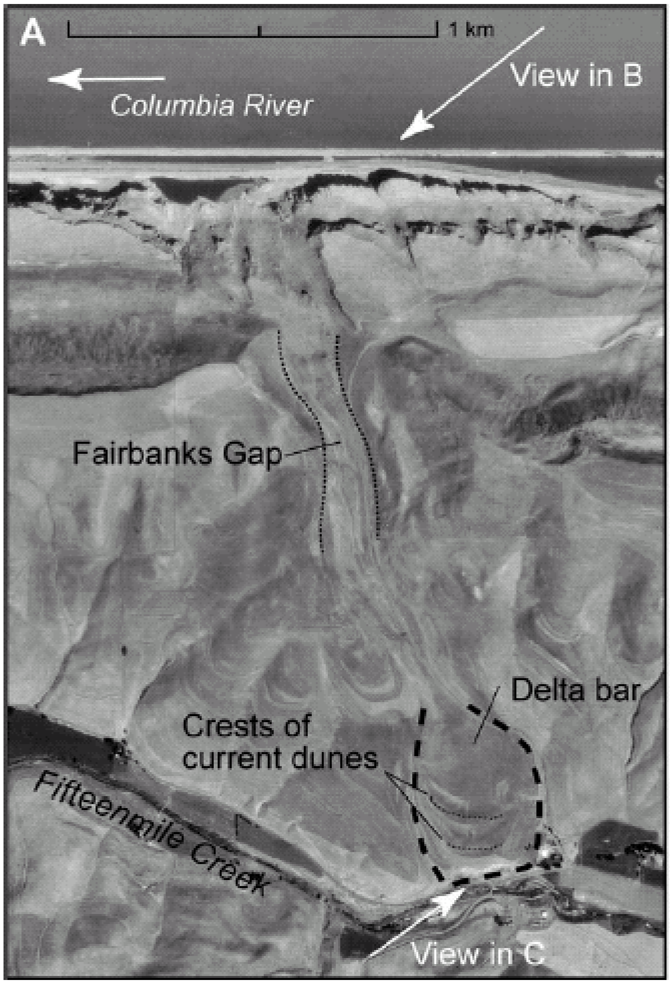
Petersburg Bar is located west of The Dalles along Fifteen Mile Road, and represents an area where the Missoula Floods overflowed the Columbia Gorge. As the flood waters flowed turbulently down the gorge and spilled over the edge, dropping down the back side, the current would have formed a zone of deposition, much like you see in a much smaller stream. Gravels that were carried in the floodwaters dropped out where the water slowed down slightly. Peterson bar is the result of one such spillover. Because the current was not flowing horizontal, but was moving at an angle, downhill, the layers of gravel were deposited at an ange as well, and this resulted in cross stratification. It doesn't show up well in the photos, but these cross stratifications were easily seen as we viewed an area, shown in the photo, where Person Bar was cut in modern times. So while much of the gorge was scrubbed by the enormous power of the flood, some sections received deposition, mostly of gravels, pebble and boulders. You can see the sorting that occurred here, it is quite obvious. It is interesting to note that while there have been large depositions, only something like one percent of the eroded materials have been accounted for. Ninety nine percent of the eroded materials from the Missoula Floods are somewhere (up to 700 miles) off the Pacific coast of Oregon.

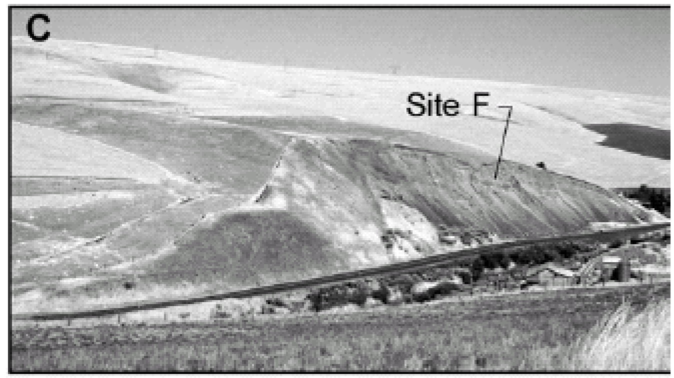
3-3 Fairbanks Divide **



Fairbanks Divide, also along 15 Mile Creek, looks like a gunsight directly through the canyon wall. Old Moody road cuts due north here, directly through the gap. Here, at high water, a large spillover occurred. The flow of the main Missoula Flood would have been an unbelievable 5,500,000 cubic meters per second. The main divide is scoured, so the flood was moving rapidly through here. To the east and west, only a few meters above the gap, you can see that soil deposits were not scoured from the basalt bedrock, thus we can conclude the flood spilled over here, but did not go much higher.

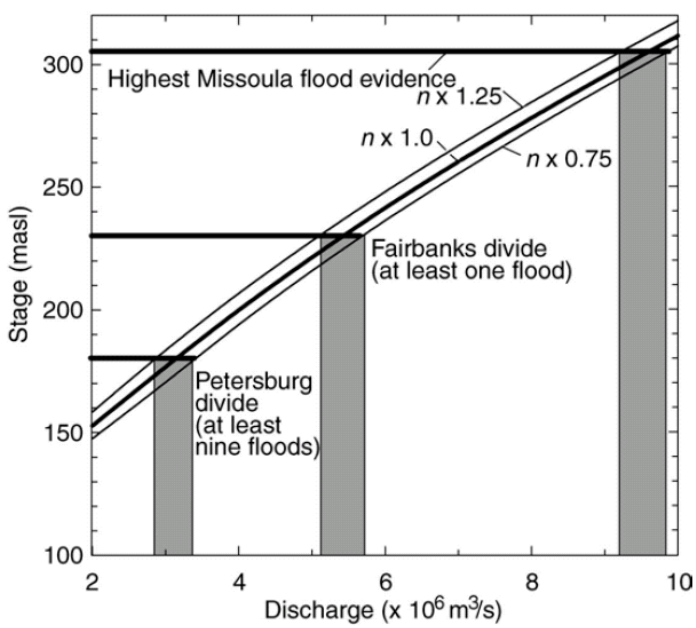


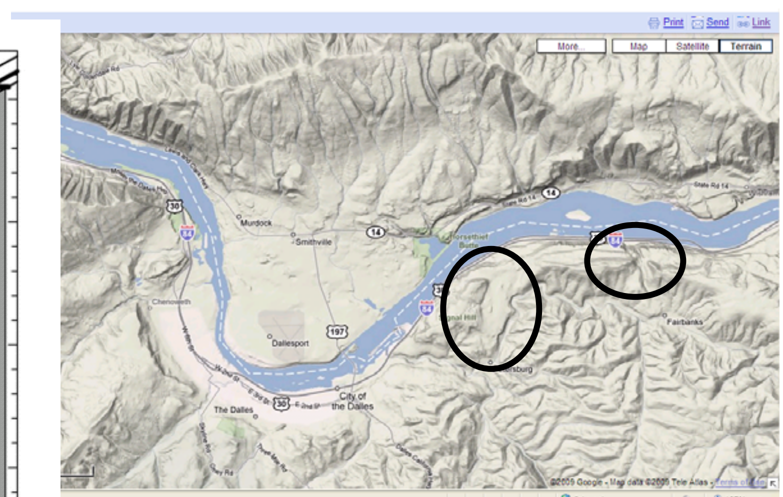




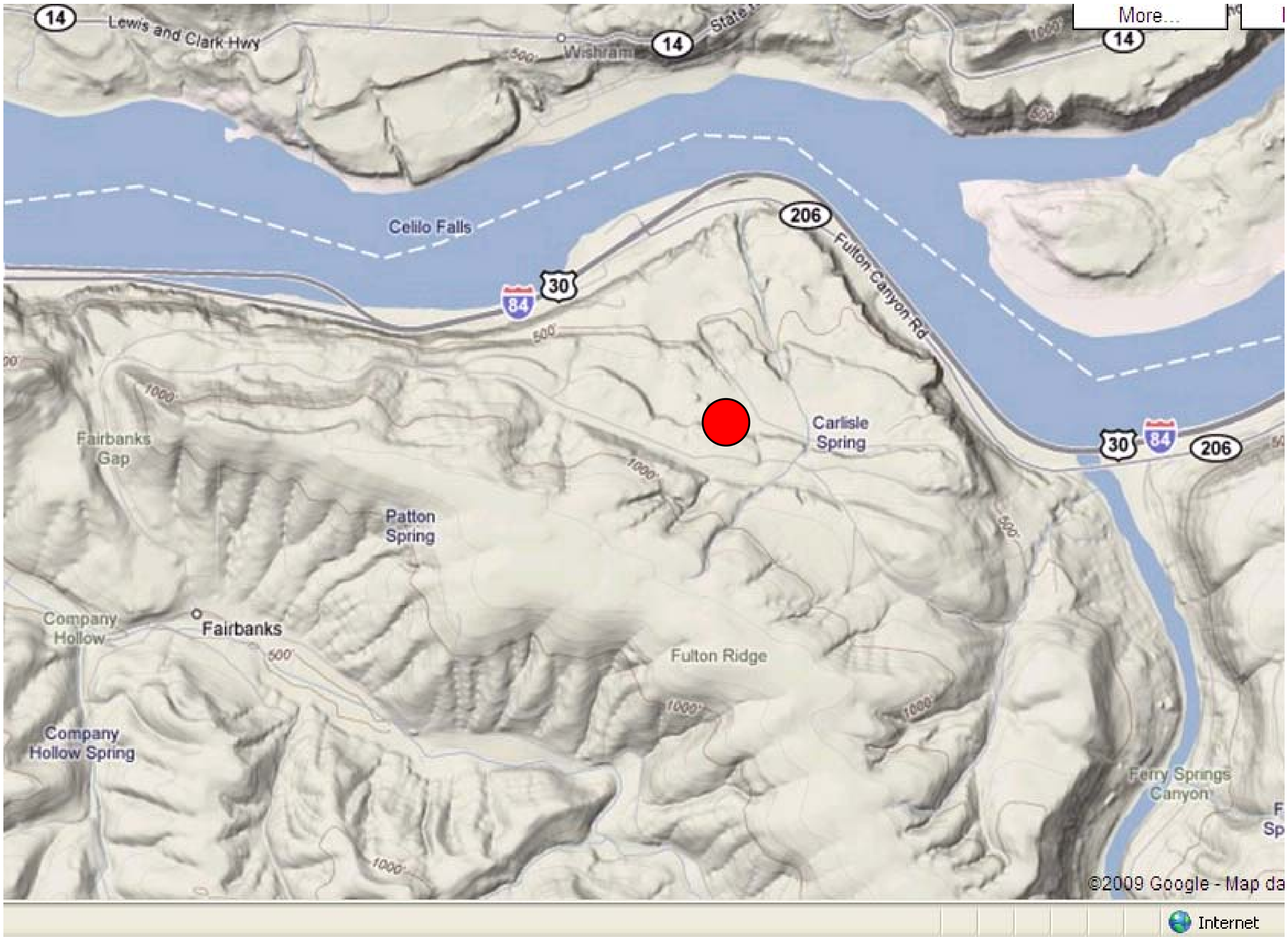
Fairbanks gap spillover left a delta bar similar to the one at Petersburg bar, for the same kinds of reasons. Flood gravels with cross stratification were deposited here. The imbrication of the gravels indicates the downhill direction (to the south) of the flow. The photo at left is an excellent overview of the result.

The depth of flood at Petersburg gap was somewhere around 180 m, at highest water, while the depth at Fairbanks was about 230 m. These different depths are a reflection of the width of the gorge at these two points. At Petersburg gap, the gorge is much wider, so a spillover, as opposed to inundation, would naturally occur at a lower level there. The eastward circle in the small map below represents Petersburg gap, and the western circle is Fairbanks.





3-4 Celilo Falls Overlook **



Celilo Falls Overlook is not so much a stop as a general location along which we traveled after we headed eastward on the southern rim of the Columbia Gorge, from Fairbanks Gap. Several things are apparent along this section of Old Moody Road. At about 300 meters above the Columbia River, the basalt outcrops disappear. You can see this easily as you drive. The 300 meter line approximates the fullest extent of the largest floods. Remember, they were moving something like 60 to 90 miles per hour, laden with rocks, silt, ice and other debris. The floods stripped away all soil, and even bedrock. Above that line, no or very few basalt outcrops are visible. Deposits of the Dalles formation topped by glacial loess deposited by southerly catabatic winds off the Cordilleran Ice Sheet at about the current boundary of the U.S. and Canada, are still present and undisturbed except by humans. Along the upper sections of the canyon we saw evidence of productive agriculture, impossible where there is only bedrock, and this is the deposition to which I am referring.

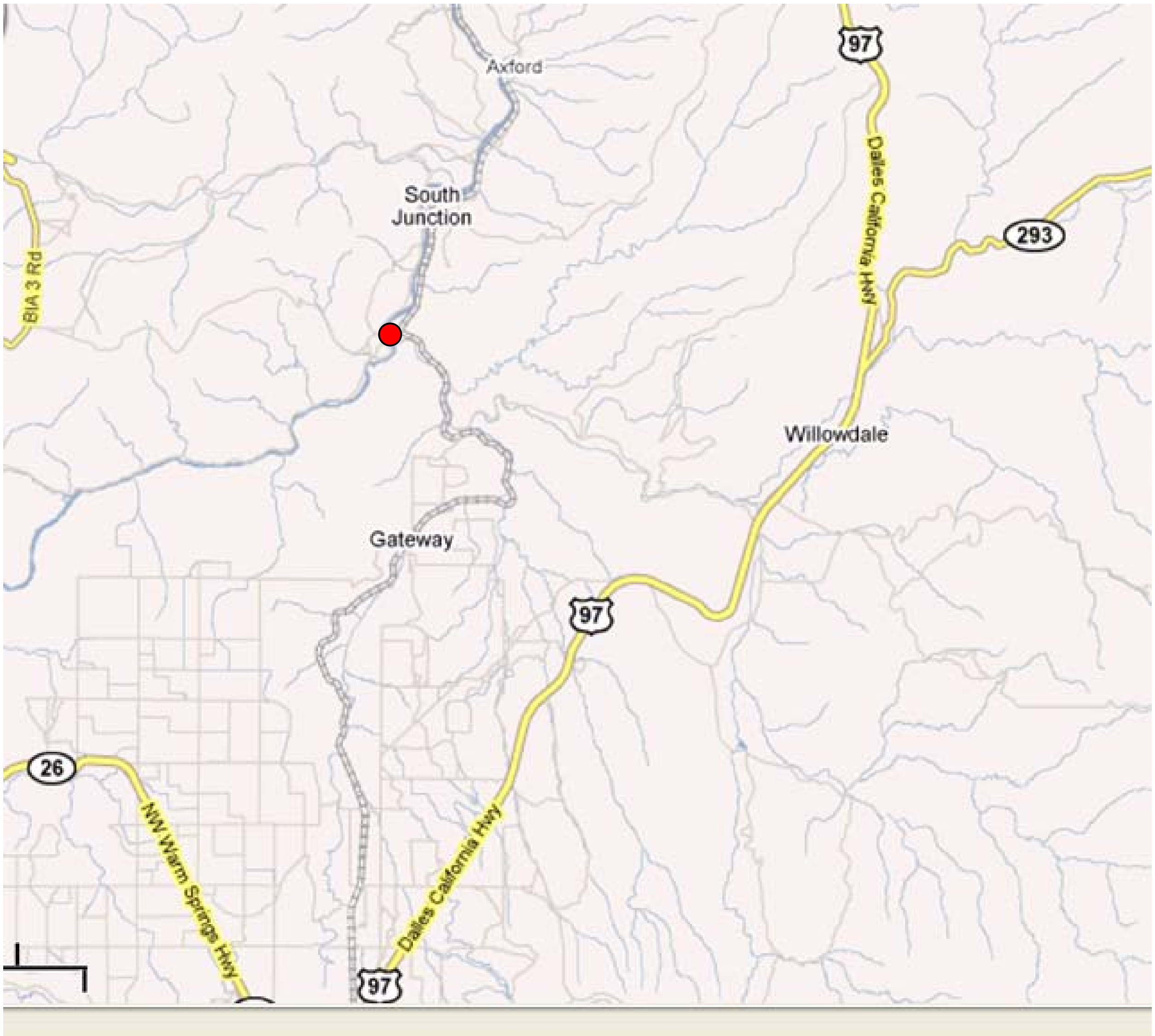
Along this drive, there are spectacular views that show the character of the Columbia Plateau, dissected by the enormously impressive Columbia River Gorge. Here it is possible to feel the incredibly power that shaped this area of the world. As we looked across the Gorge, to the north, it was interesting to see how quickly alluvial deposits have accumulated in the lower sections of the gorge. We know these accumulated in about the last 12,000 years, given that the floods scoured the gorge clean prior to that.

Dissected alluvial deposit in the gorge.

The 300 meter line seen for miles.

Above the flood level, agriculture is possible because loess deposits are still there.

4-1 Trout Creek Road Cut **



At the beginning point of the rafting trip down the Deschutes, we camped at Trout Creek confluence. If you look at the hillsides around Trout Creek, you will notice high, flat plateaus (buttes) farther away from the river, and lighter a colored formation below that, which forms steep hillslopes, which reach down to the Deschutes river. The buttes are “capped” with several layers of often columnar basalt. These basalt layers are Columbia River Basalts, erupted 6 to 17 million y.a. The CRB’s are underlain by John Day formation. The John Day formation was formed 38-25 m.y. ago and is made of ignimbrites (welded tuff), volcano-clastics (broken up rocks from various other volcanic events) as well as fluvial (river) and lacustrine (lake) deposition of the parent material. It is rather weakly associated, erodes easily and is given to mass wasting (landslides and slumps). We cannot see the layer that underlays the John Day formation. It’s called the Clarno formation, and we discuss it later in our field trip. Uplifing between the area around Whiskey Dick, down to about river mile 62 caused the Clarno to be uplifted, so it can be seen there.

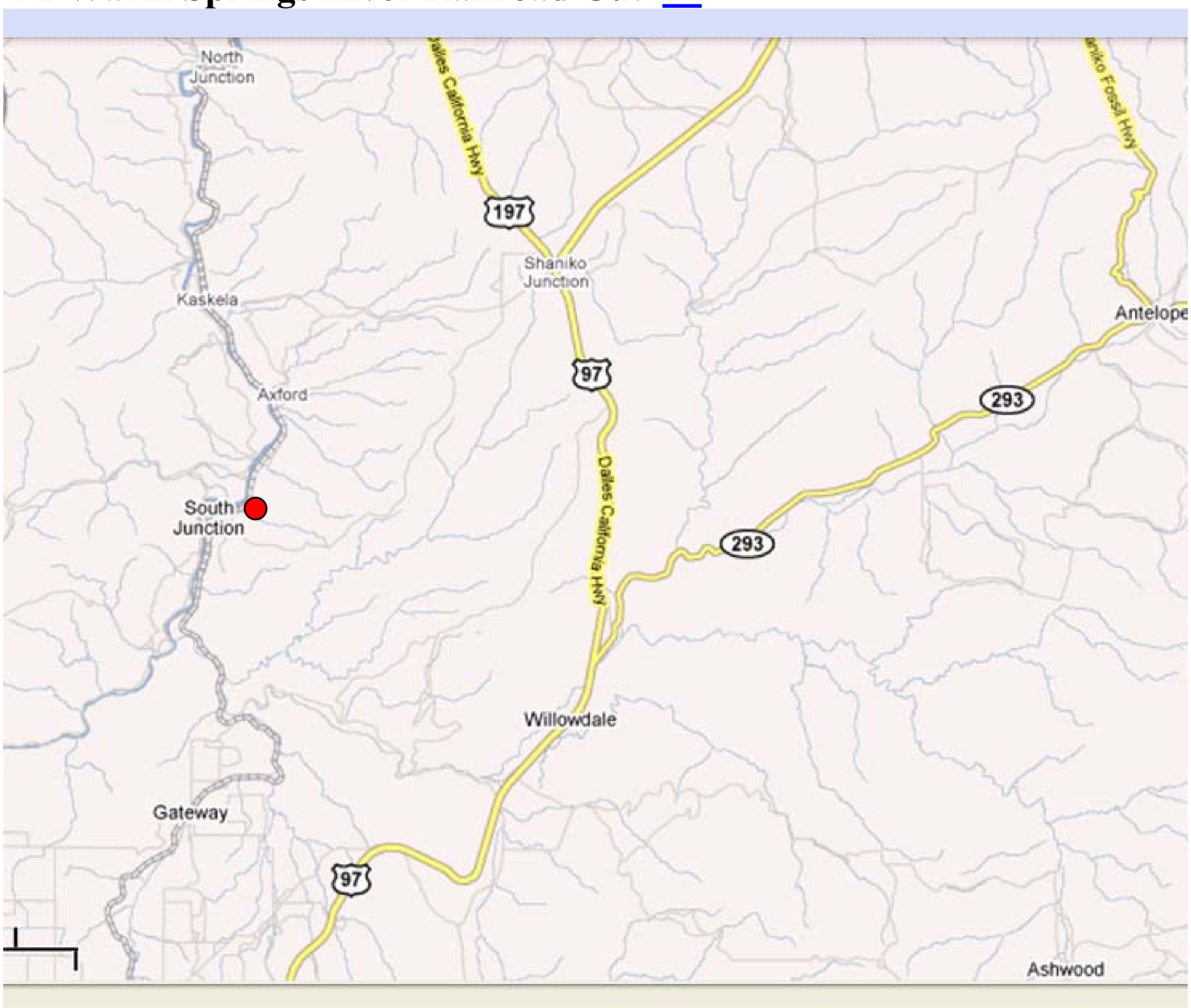
The layering of various formations is called stratification. Each layer is a stratum. In the general region, Clarno formation was laid down first, then the John Day formation, and then the Columbia River Basalts (17-6 m.y.a.). Geologists use strata to help correlate events in disparate areas that share the same strata. The Columbia River Basalts have been broken down further into individual flows because scientists at Hanford Nuclear Facility undertook intensive studies of their mineral and crystal structure in order to try and understand how the CRB’s, as they are often abbreviated, are laid down throughout the Columbia River plateau, and how that might affect spreading of the contaminated groundwater at Hanford, which is located on CRB’s. This has added greatly to geologists ability to correlate events associated with CRB’s.

Trout Creek is not the widest area on the Deschutes but it is wide enough to allow floodwaters to slow down, and this has resulted in the depositon of rounded clasts, and other sorted, smaller materials, into terraces. In other words, as we saw on the North Santiam River, floodwaters carrying suspended and dissolved material slow down in wide spots, losing some of the energy that allowed them to carry these materials to the wide spot. Heavier clasts drop out first, then smaller and smaller materials.

Near our campsite, there is a cutbank exposing the layers of a river terrace. You can see many rounded clasts embedded in finer material. Some of the exposed rounded clasts are clearly imbricated. Also there is a layer of pumicious material that has been correlated with a Mt. Jefferson eruption about 100,000 y.a. At the top of the cut, the darker color material represents some soil development, which occurs very slowly in this part of Oregon due to the arid climate. We can date the terrace layers between the pumicious layer and the soil layer, where trees are growing,from between 100,000 years ago and perhaps the last hundred years, given the lack of much soil development. From the size of some of the clastics, some fairly large flooding occurred here during that period

A good view of the rounded clastics, finer sediments, pumicious layer from Mt. Jefferson, soil development and older layers underlaying the Mt. Jefferson pumice/ashfall. Geologists can use these layers, and correlate them to other layers downstream, to help reconstruct paleoflood history. As we'll see at the next stop, the Mt. Jefferson layer is easy to see, and useful in dating, like many layers of volcanic doposi.t.

4-2 Warm Springs River Railroad Cut **



At the confluence of the Deschutes and Warm Springs River, the valley is quite wide. This is always a good place to look for flood deposits, including paleoflood deposits. As we have already discussed, the river can slow down here, and deposit alluvial material it has been carrying. At the railroad cut near the confluence, we examined a river terrace, somewhat similar to the one we saw at Trout Creek. The sediments deposited here are finer than those at trout Creek, and well sorted, with many layers. These are clues that the water was indeed slowed down here, which is not surprising.

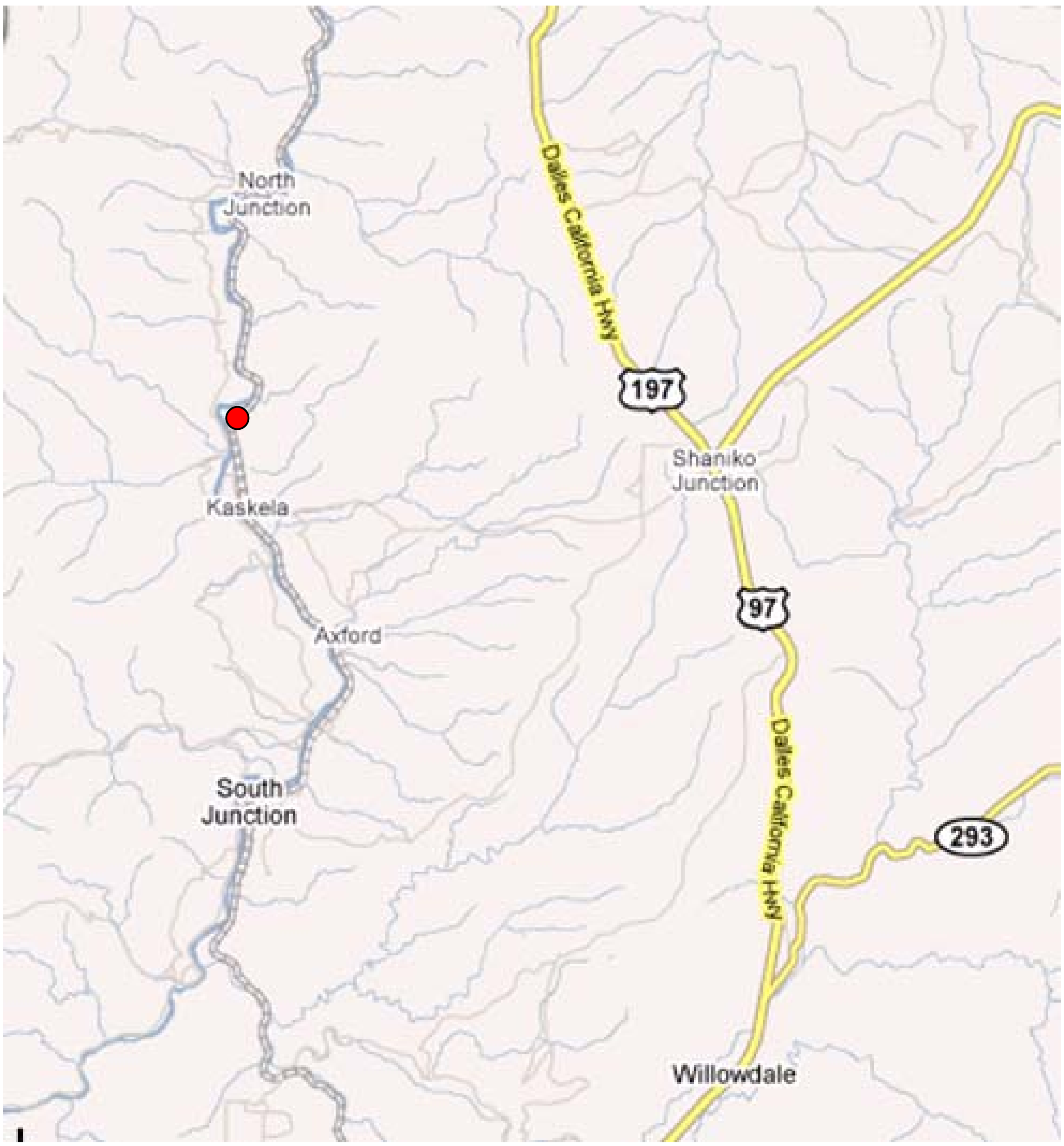
Also here we see leaching of Calcium Carbonate. Leaching is apparent on many of the terraces along the river. In the arid environment of this area, since not much precipitation occurs, water does not penetrate more than about a meter into the soil. As the precipitation falls, it dissolves the more soluble cations (calcium is a very soluble cation) from the surface and carries them downward into the soil or regolith. The penetration depth of the water tends to be somewhat the same most of the time, so that a layer of deposited calcium carbonate is formed. Calcium carbonate is the result of the interaction with the dissolved calcium cations with air, as the water evaporates. Calcium carbonate is whitish in color, so it doesn't always show up in lighter colored deposits. Dropping some hydrochoric acid onto calcium carbonate makes it "fizz" as carbon dioxide is give off from the acid reaction with the calcium. This is a good field diagnostic test. Clays are fine materials, and easily dissolve in water. Clay layers form, in the same way calcium carbonate layers do.

Because the layers here are very thin and contain fine materials, it is probable that this was a lake at one time. We did not discuss this in great detail at all, but it doesn't take much imagination to see that this wide area could easily contain a lake if there were a geologic dam downstream. Probably sometimes this was a lake, while at others it was a river bed, where deposition of clastics and larger materials occurred. You can see that in the terrace.

Another interesting strata related situation exists at this particular cutbank. The John Day formation is directly overlain by lacustrine and pluvial deposits, and the stratification within the John Day indicates a cline to the north. Uplifting/folding occurred to create this cline, and then erosion "cut" the top off of it, then alluvium was laid on top of that. When a layer (in this case the rest of the John Day) is missing we have an unconformity. In this case it is an angular unconformity, so called because the John Day formation here is angled, not "flat".

At right is a photo of an outcrop of John Day formation bedrock. Below it is a colluvial hillslope. Colluvial hillslopes are created when parent material is slowly eroded and broken up, moving downhill. Colluvium is eroded material moved by gravity, biological activity (plant roots break up rock, rodents dig through colluvium and move it further, etc) or human activity. Colluvium refers to dry movement of eroded material while alluvium refers to material moved by water.

4-3 Camp at Whiskey Dick / Hydrology Lecture **



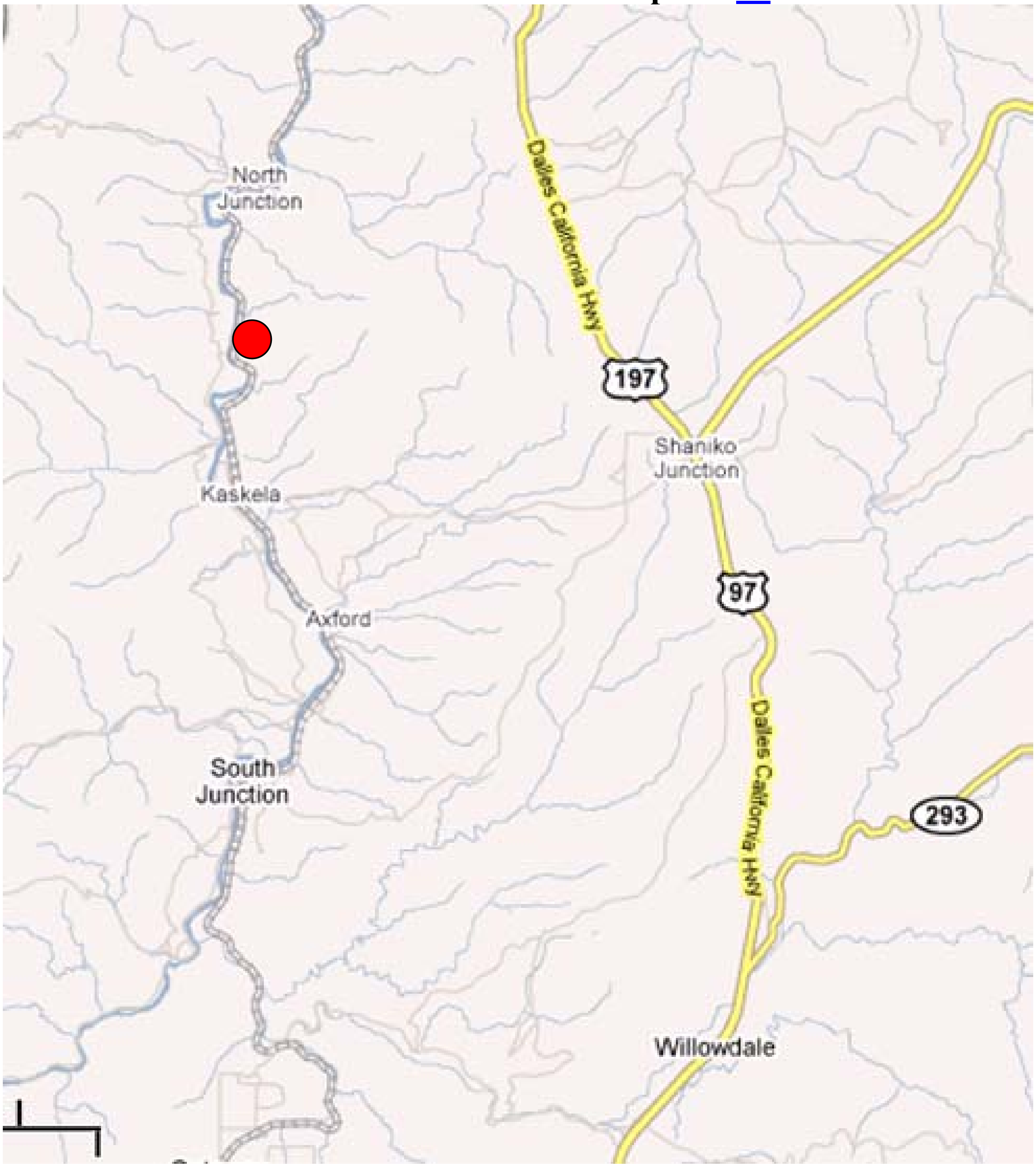
Hydrology is the study of water and its behavior. Paleohydrology extends that study into the ancient past. As we have seen in the literature and heard from Dr. Taylor, hydrology is really a dynamic interaction between the land, the climate and time, and it is complex. In the Pacific Northwest, it includes often violent episodes or events, and using geologic and hydrologic methods, we can reconstruct the history of events and use that to predict something about future events as well as long term behaviors of water systems.

The Deschutes is the most stable river system of its size in the United States. It is unique. Its maximum and minimum flow differ by a factor of only 1.5 in a typical year. It flows at a constant rate most of the time. Compare that to the Willamette River (factor of 10 change) or the John Day (factor of 30) and it is easy to see why we call the Deschutes flow almost unchanging. This steady flow is due to several factors. The High Cascades to the west maintain snow pack well into July and in some places year round, allowing slow, steady melting snow to enter the ground and percolate downward, as compared to rain which often runs off quickly. The large grain character of the volcanic materials that make up the basin allow groundwater to steadily flow into the river. As we rafted the Deschutes, many springs higher up in the valley were apparent, marked by green strips of vegetation in some drainages, surrounded by brown, arid slopes.

Of course the flow is not always steady. In 1996 we saw an example of the type of meteorological flooding that can occur when large storms deposit heavy winter snows that are unseasonably melted by warm fronts that follow the large snowstorms. Because the east sides of the High Cascades receive a lot of snow when this happens, unseasonable melting can cause flooding similar to that we see in the Willamette Valley during a weather episode like this.

And of course, as we see again and again, the Deschutes has been subject to damming by lahars, lava flows and landslides, which create geologic flooding when these natural dams eventually fail. So while we say that most of the time the Deschutes has a remarkably steady flow, this is still punctuated by large flood events.

5-1 Hike to "The Pot" Overview / Landslide Complex **



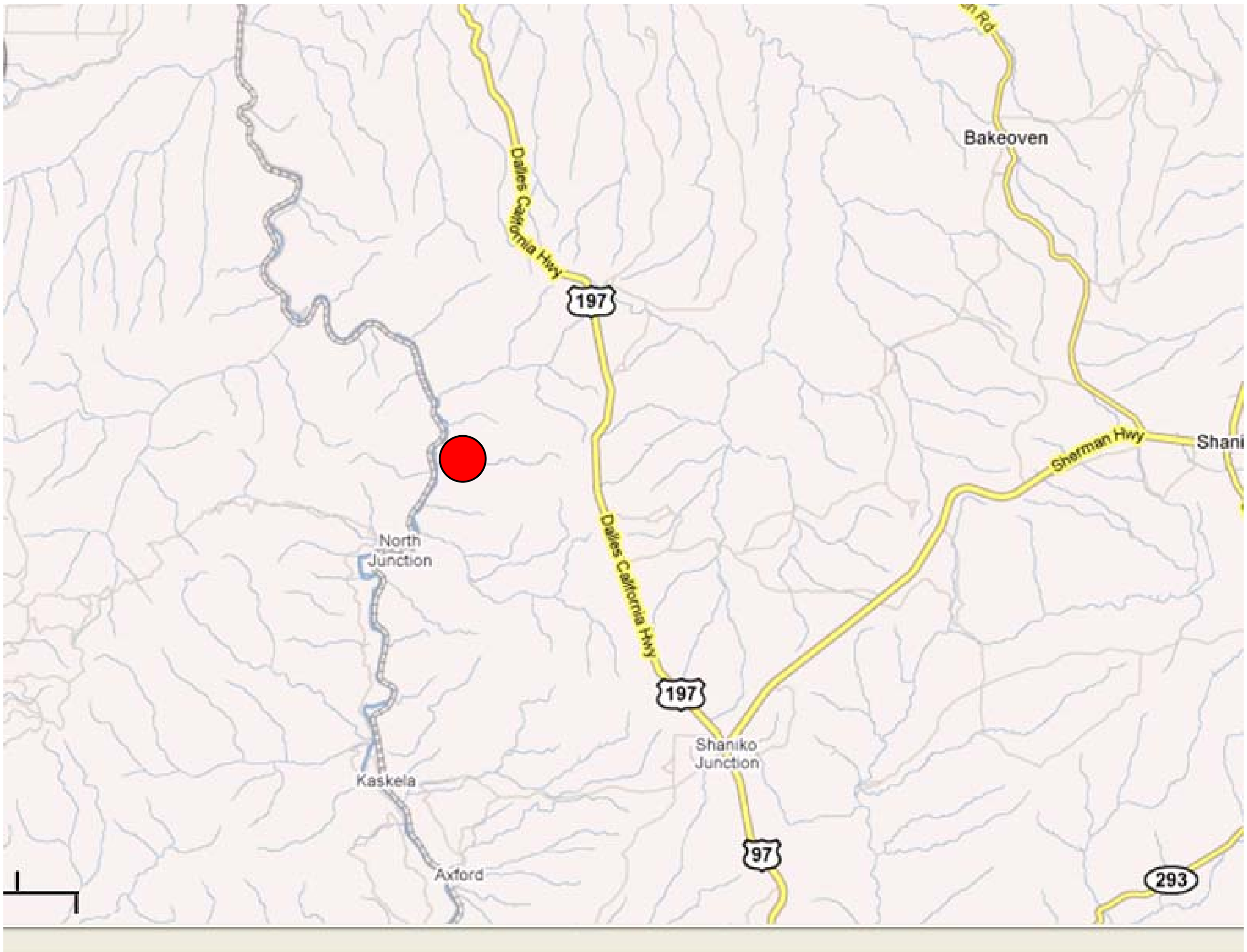
Recall that the Clarno, then the John Day and finally, the CRB formations were deposited in this region, in the order just listed. From here to about river mile 59, the area has been uplifted, so that the CRB cap has been eroded, long ago. Both the John Day and the Clarno are well known to be weakly bonded formations, prone to land slide and slumps. At Whiskey Dick pullout, a spectacular example of a very large slump of the Joahn Day is easily viewed, if you climb up above the cliffs on river right.

Much of the time, when we look at hillslopes, we see examples of colluvium, the movement of material down the hill by gravity, plants and animals. Typically we imagine this as a slow, uniform process. In fact, until well into the 20th century, both biology and geology insisted upon the fact that change occurs incrementally, very slowly. This is not the case at all, much of the time. The picture should be a mix of slow movement downhill, punctuated randomly by large movements of big chunks of land over sometimes relatively large distances, in random locations, intimately related to the type of material.

Steep hillslopes are eroded by gravity, wind, ice, water and animals. Water can typically only move material as alluvium if it is focused in a channel. In an arid climate like we see in central Oregon, hillslopes that have no drainage erode without the effects of water and ice, for the most part. The slope can be analyzed, and broken into parts- like a steep upper ridge, shallower but still eroding slope, and deposition area with a somewhat shallower slope, at or near the bottom. We walked up one of these when we visited the overview of The Pot. You can analyze rates of colluvium deposit. One way is just to look at the rocks and size the lichens. They do not grow fast, and you typically won’t see them on disturbed rocks.

Once we climbed the steep hill leading to the top of some cliffs (of John Day formation) we looked up and also to the north at The Pot. The land looks disturbed, and to my untrained eye it was difficult to put a finger on just why. However, if you look carefully at the strata in the outcrops in this area, you can see that the tilt slightly upward as compared to most of the nearby strata. The fact is that at The Pot, about 3 cubic miles of John Day formation slid down slope in a rotate fashion, so that the parts facing the river tilted up a bit, while the parts next to the hill slid downward. Geologists think that for a slide of this proportion to occur, a seismic event, an earthquake, may have been required to trigger the event. An event like this is yet another example of how large movements of land can dam a river valley.

5-2 Mile 70 / Jumping Rock / Clarno Formation / Hydrology Lecture 2 **

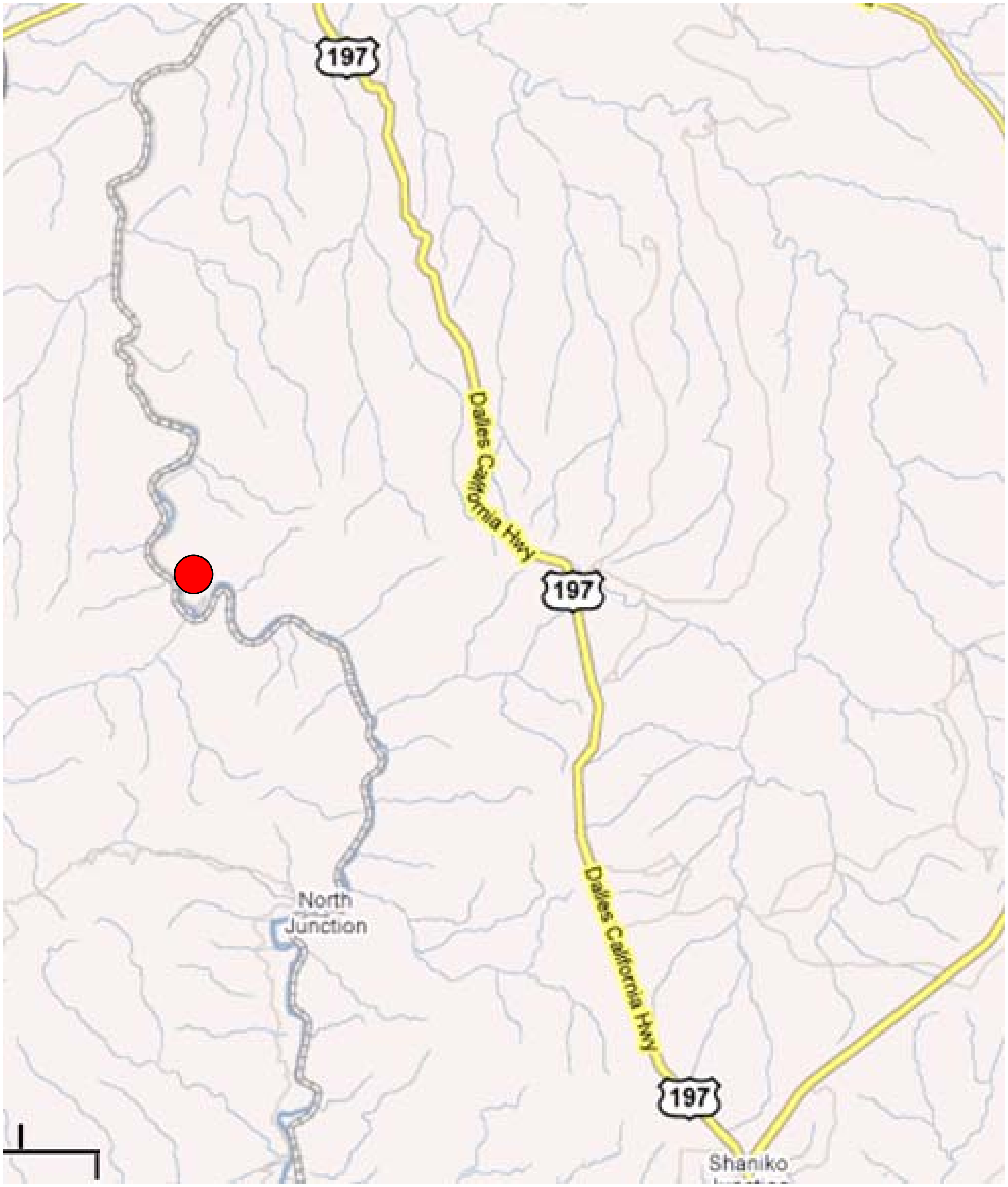


We stopped at about river mile 70 to eat lunch. This is about 2 miles below the first appearance along the river of the Clarno formation. The "Clarno is similar to the John Day in that it consists of various volcanic deposition. It is usually darker than the John Day, and looks much older, because it is, about 40 million years old. It just looks very beat up. The picture shown here is a rock off of which we jumped during our lunch break. It is actually an island, mid-river. Note the chimney like appearance, a common feature in Clarno formation rock. Clarno formation has been subjected to intense groundwater heating, so that chemical changes have occurred to portions of it. This has the result that some portions of rock, those affected by the heated groundwater, are more resistant to erosion, and so form spire like shapes as the less resistant rock around them is eroded away.

Wile we ate lunch, we noticed organic debris deposited in the trees, at about a meter off the ground. This is probably deposition from the 1996 flood. Ed Bartlett told us there was a gravel bar on river left, upon which one could walk from our lunch site to the left bank of the river. Currently, there is a shallow channel there. The narrow canyon here resulted in increased depth and speed and the volume of current is compressed. During times of flood, this means larger bedload can be transported, as compared to other sites that are less constricted. We discussed, earlier, that the John Day formation, though similar to Clarno, is softer, and so results in increased erosion, and resultant breadth of the canyon there.

Typical Clarno Formation Rock.

5-3 Camp at Buckskin Mary **

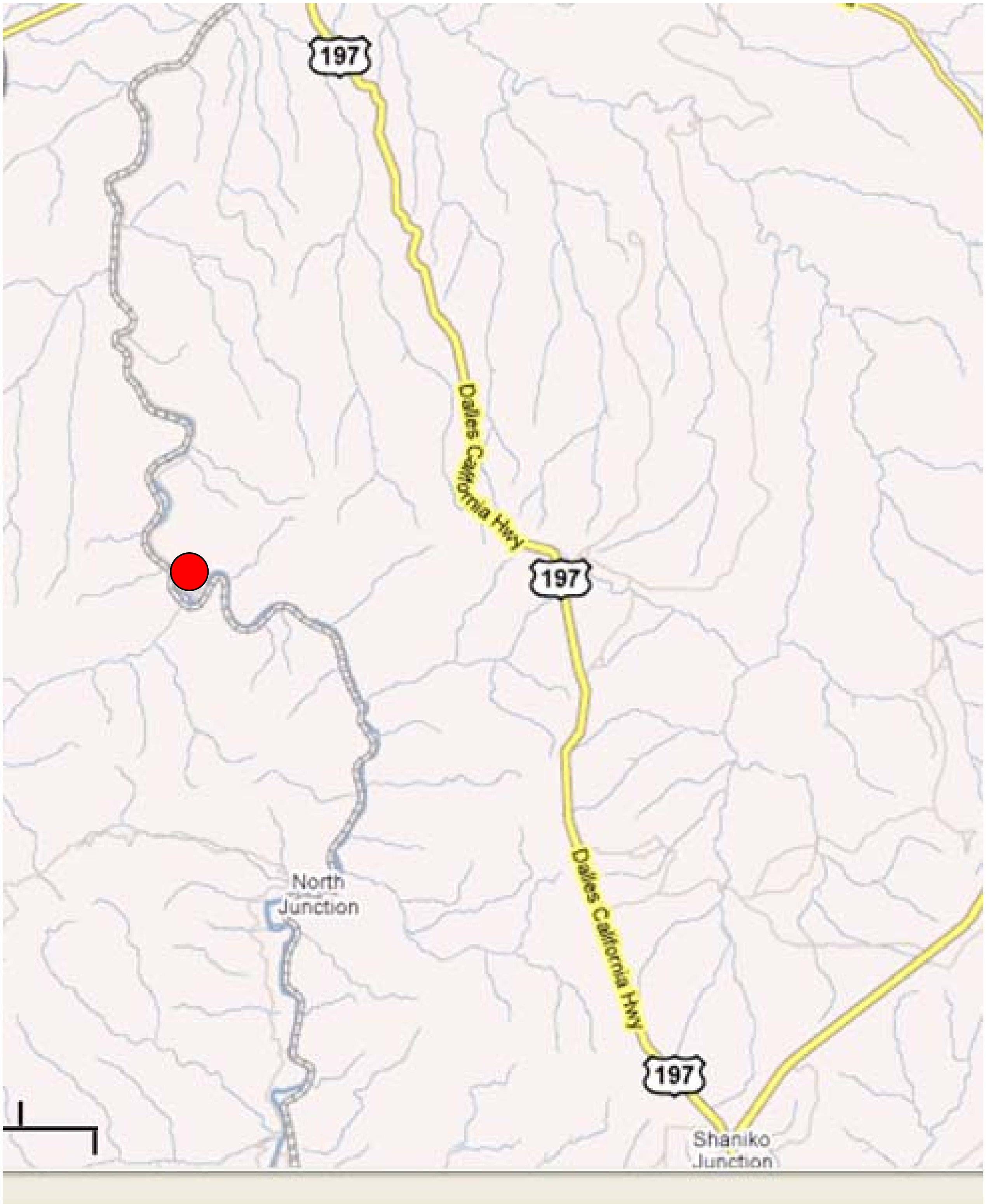


Here we stopped to camp, and discussed the age and appearance of the Clarno again. I will leave out the Dant Debris flow, as we discuss it in the next stop. We discussed the formation of soil. Soil is the result of biochemical and physical alteration of regolith over time. Typically at takes about 10,000 years to form a soil, depending on climate, of course. The soils in this area almost always have an aridisol. These occur, as I described in more detail earlier, because $CaCO_3$ forms as Calcium is dissolved and then precipitates down deeper in soils that are arid. The layer of an aridisol tells you about how deep the moisture in an arid soil is penetrating.

There is no soil around where we camped, it is all medium to large regolith.

A closeup of Buckskin Mary shows one of the boulders that were part of the mass wasting that occurred here. The photo above is downstream of the main rapid, but you can see the bubble line caused from up river.

6-1 Dant Debris Flow / Buckskin Mary Hillslope Observations **



At the Dant Debris Flow, the hillsides in the area failed in a spectacular fashion. I blew up the photo from 5-3, it shows the best view I could find of the remnants of the debris in the bottom of the canyon. This flow blocked the river, which eventually chewed its way back through, leaving a few boulders to form Buckskin Mary rapids. One day, these will be gone too.

The deposition you see across the river is a mixture of all kinds of regolith, some of it large. Another example of catastrophic geological damming, knickpoint, failure and flooding.

6-2 Outhouse Flood Bar **

At the Outhouse Flood Gravel Bar, we visited another wide section of the Deschutes river valley. This area was studied by several geologists trying to rebuild paleoflood events, and it was here we discussed it in some detail. As we have seen, any time geologists want to find clues about paleofloods, they look in wide parts of the valleys they are studying, because it is here, where flood waters slow, and also pool, that alluvium is likely to be deposited, and also likely not to be eroded later. The rocks here at the outhouse flood are somewhat rounded, meaning they were placed here by water. They are large, so the water had to be moving fast, and there had to be a lot of it. In fact, one of the Dant floods mentioned in our literature was nearly 4000 cubic meters per second. Our guide, Ed, mentioned to me that the Deschutes was currently flowing somewhere around 4000 cubic FEET per second. 1 cubic meter is 34.328 cubic feet. 4,000 cubic meters per second translates to 137,312 cubic feet per second. That is 34 times the current flow of the Deschutes. That was a tremendous flood.

We wondered how long ago the last large rocks were depositied. We noticed lichens that were very large. We did not calculate the age from that, but discussed how lichens can be used to do so. We discussed meteorological vs. geological floods.

Geologists were originally confused about the largest Dant flood, for example, and claimed it was a geological flood, but later revised their opinion, and said it was a very large meteorological flood. Clearly the Missoula Floods were each beyond the scope of anything meteorological. In general, it seems that the scope is highly dependent upon specific events, not generalities. Still, leaving the Missoula Floods in their own separate category. we can certainly say something about the character of geological floods. They happen suddenly, with much greater force, typically, than meteorological floods. Deposition from geologic floods decreases downstream as these floods are more quickly dissipated than meteorological floods. You get a more localized effect, on a part of a watershed or in a particular river/stream. The effects are usually extremely violent, as dams suddenly give way and release entire lakes downstream. Meteorological floods get larger downstream, due to the aggregate effect of collection by an entire watershed, and deposition doesn’t typically localize- it is spread out, and will be larger the farther downstream you go. Meteorological floods build up, occur and subside gradually rather than suddenly, as a general rule, compared to geological floods.

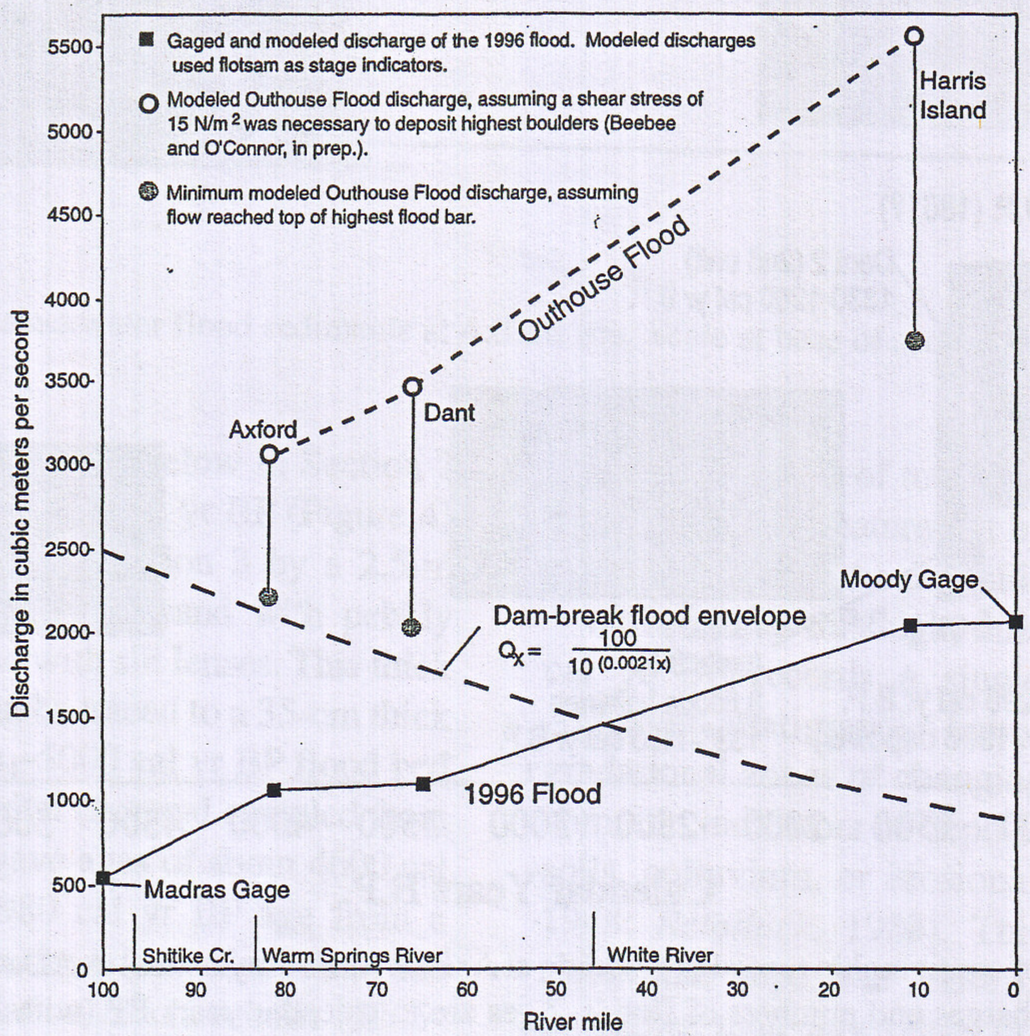


Figure 10. Comparison of modeled discharges of the Outhouse Flood with gaged and modeled discharges of the February 1996 storm flood. Envelope defining the peak discharge attenuation of historical dam-breach floods is from Costa (1988). In this equation, x is the distance downstream from the breach in km, and Qx is percentage of discharge at the breach.

The graph above shows a left to right, upward slope for both the outhouse and the 1996 flood, both on the Deschutes. The Outhouse flood didn't occur in human experience, so its estimated. Still, both graphs show increased deposition, in a gradually increasing fashion, of flood product downstream. So, it was really big, but the outhouse flood was most probably NOT a geologically caused flood, it was probably meteorologically caused.

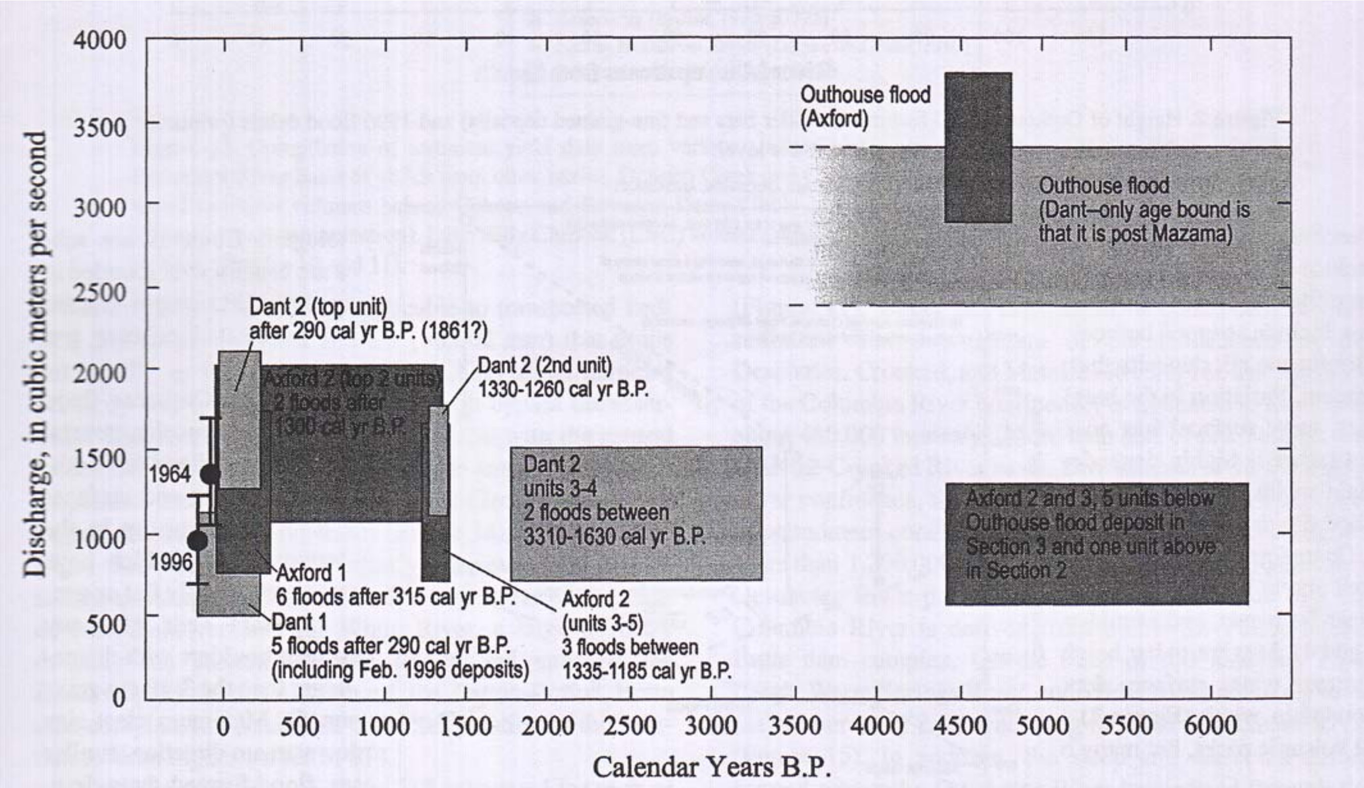


Figure 16. Summary diagram of stratigraphic record of flooding at Axford (dark gray boxes) and Dant (light gray boxes) study sites, showing ages, discharges and numbers of floods. Ages are in calendar years BP (with A.D. 1950 regarded as "present"). Also shown are estimates for the 1964 (adjusted for regulation) and 1996 flood discharges at the Axford study site.

Above- Relative sizes of various floods. Note how big the outhouse flood is. That is why scientists at first thought it was geologic in origin.

Last, but certainly not least, here we are re-entering Columbia River Basalt formation. This second time down the river, I noticed a lot more depositions of non-basaltic material sandwiched between the basalt layers in places. These represent non basaltic deposition, of course, probably from the ancestral cascades. These would have built up (average time between CRB flows was 35,000 years) and then been sandwiched by CRB that reached this far west.

Course Synthesis and Summary **

A Landforms and processes Associated with western and central Oregon Rivers.

1. What are the dominant processes that influence western and central Rivers? In your narrative include both a discussion of both geologic and tectonic variables. The dominant processes in western and central rivers include: Tectonics and uplifting which create landforms to erode. Volcanoes that result from tectonics, and which create volcanic products such as tephra, ash, lava, adding to the landforms and also damming rivers which in turn create deposition, and erosion. Dam failures at knickpoints and resultant catastrophic flood events that follow. Ice age damming with same result, though we don't see that presently as a factor. Meteorological floods are not considered individual geologic events but I think a case can be made for considering these as geologic forces- water acting upon the landforms, repeated over time. Whether they are truly geologic or not, they act in a similar fashion and are definitely a major shaping force.

2. What are the landforms associated with lower hillslope and valley environments along western and central Oregon Rivers? Oregon Rivers, with the exception of the lower portions of waterways in the broad Willamette Valley, typically have steep slopes. The uplifting Cascades and Coastal ranges are steep because they are uplifted and eroded, by both colluvial and alluvial forces. These rivers typically have steep slopes, increasing their erosive force. In addition, flood events, both meteorological and geological, are common, and often large, increasing the rate of erosion. Meteorological events have probably been similar for a very long time. Geologic flood events still occur due to volcanic events and landslides, damming rivers, forming lakes and then flooding catastrophically when the dams eventually fail suddenly. Still, in our short tenure in Oregon, we humans have not seen the more violent geologic events associated with the ice ages or really large volcanic events (as big as it was, St. Helens was actually very small as volcanic eruptions go), nor have we seen really large landslides like those that occurred in the Deschutes, which formed lakes, and led to the creation of the rapids we all like to run. In short, Oregon rivers have a violent history over geologic time, they are steep, prone to floods, and have a large impact on the landforms we see.

B Meterologic and Climate Controls on Fluvial Processes in western-central Oregon

1. Compare and contrast precipitation patterns west of the Cascades vs. east of the Cascades. Western Oregon receives a tremendous amount of rainfall brought from the west, over the Pacific Ocean. As we move eastward, across the Cascades crest, we see a rainshadow- Eastern Oregon receives 10-20 inches per year, not the 60-150 or so inches we see in the west. This has a profound effect on the usual weathering on materials in the east vs. the west. For example, Mt. Washington is a volcano that is actually younger than Black Butte, yet Black Butte remains almost a perfect cone shape, while Mt. Washington is tremendously eroded. Only a few miles separates these two features. Black Butte has never been acted upon by the glaciers that carved up the more westerly Mt. Washington, and maintains most of its original shape, even though it is older. **What are the dominant controls on these precipitation patterns?** Weather systems approach the Pacific Coast, and the Cascades, from the west. The adiabatic cooling of air as it rises up the western flank of the cascades results in a cooling of the air, and less and less ability to retain moisture. As moisture laden air is cooled, it dumps more and more of its moisture as precipitation, so that by the time it has crested the cascades, and begins to warm, it has given up all the moisture it once had, and is now dry, with a low relative humidity. That is the rain shadow effect.

2.What types of meteorologic conditions cause flooding west of the Cascades?
What meteorologic condition causes the highest magnitude floods?
West of the Cascades, even relatively normal winter precipitation can cause mild flooding. Higher than normal precipitation causes more flooding of course, but the most severe meteorological flooding results when large, often closely spaced systems dump large amounts of rain at low elevations and snow at higher

elevations, followed by the "Pineapple express" as we often call it- a wet, warmer weather system that dumps rain at unusually high elevations and melts large amounts of snow, both as a result of the high temperature, and the added effect of warmer rain. When this happened in 1996, downtown Portland was underwater, and many bridges in the Willamette Valley were flooded out.

3. What types of meteorologic conditions cause flooding east of the Cascades? Having at least 10 winters camping high up on both sides of the Cascade crest, I can say with confidence that the high portions of the east side of the crest still get a large amount of snow. Often the very large weather systems that dump a lot of snow on the west side also drop a large amount on the east side. When the pineapple express follows closely behind, if it is large enough, it too affects the east side, resulting in very large flood events in the Deschutes, for the very same reasons it causes large floods on the west side. Data shows the 1996 floods occurred on the west side and also in the Deschutes.

C. Geologic Controls on Fluvial Processes in Western and Central Oregon

1. What types of climatically-driven and tectonically driven geologic processes result in large magnitude flooding in western and central Oregon? I think I have explained the climatic processes that cause flooding, but of course, we need to understand why this can even happen in the first place. No Cascades, no flooding, or at least a lot less. The Cascades are created from tectonic subduction of the eastward moving Pacific plate beneath the westward moving North American Plate. Granted, there are smaller plates (or perhaps "sub-plates") involved, like the Juan de Fuca, but the idea is the same. Tectonic subduction results in melting of the subducted plate and inland volcanic formation and uplifting- in our case, the Oregon Cascades. The result of weather on this system is periodic flooding, under the conditions explained above.

But one must consider other long term results of tectonics with regard to flooding. The Cascades also erupt periodically, again as a result of tectonics, damming rivers with lava flows and lahars. These dams eventually fail from the never ending erosive process of the river that was dammed, resulting in large geologically produced floods. In addition, the tectonically produced bedrock, and uplifting of the Cascades and the western edge of the High Lava Plains, combined with erosion, produces steep slopes that are subject to more erosive forces- snow, rain, freeze-thaw cycles, glaciation and also to earthquakes (again, from tectonics). The result of some of these are massive debris flows, landslides and rockslides. For example the John Day Formation- mostly tephra and other eruptive materials- is weakly consolidated, is indirectly the result of tectonic forces, and is prone to debris flows that have dammed the Deschutes in the past. These dams eventually failed, producing very large geologic flood events. We also know that landslides occur frequently in the complex coast range in western Oregon (that range is a result of tectonic accretion), and that these are also associated with heavy rains. We didn't study that, but it's a fair bet that the same kind of damming and sudden failure occurred on coastal mountain rivers.

Glaciers are a combination of the tectonically produced cascades and weather. In the Holocene, they were large enough to dam rivers, and produced powerful geologic floods when those dams failed suddenly. Glaciers also produce moraines, and some of these are still evident today. Suttle Lake is a good example of a cirque that deposited a lateral (to the south) and terminal (to the east) moraine, creating the lake. Without intervention by man, this moraine would eventually fail, and a good sized geologic flood would occur eventually.

The Missoula Floods of course, dwarf any other flood, probably in all of the known geologic history of the entire world. They too have tectonic features involved, as well as glacial forces. When one stops to consider all of these forces, their magnitude and the time scale involved (sometimes long, sometimes instantaneous), we may perhaps take a moment to marvel at the extraordinary and interesting processes that shape northwest rivers. Its awe inspiring.

2. Compare and contrast the magnitude of floods associated with meteorological vs. geological processes in western and central Oregon. I am admittedly confused about these comparative magnitudes. It appears that sometimes geological floods in some areas were larger, while meteorological floods were larger in other areas. Geologists were originally confused about the largest Dant flood, for example, and claimed it was a geological flood, but later revised their opinion, and said it was a very large meteorological flood. Clearly the Missoula Floods were each beyond the scope of anything meteorological. In general, it seems that the scope is highly dependent upon specific events, not generalities. Still, leaving the Missoula Floods in their own separate category. we can certainly say something about the character of geological floods. They happen suddenly, with much greater force, typically, than meteorological floods. Deposition from geologic floods decreases downstream as these floods are more quickly dissipated than meteorological floods. You get a more localized effect, on a part of a watershed or in a particular river/stream. The effects are usually extremely violent, as dams suddenly give way and release entire lakes downstream. Meteorological floods get larger downstream, due to the aggregate effect of collection by an entire watershed, and deposition doesn't typically localize- it is spread out, and will be larger the farther downstream you go. Meteorological floods build up, occur and subside gradually rather than suddenly, as a general rule, compared to geological floods.

D. Overview of Hydrologic and Paleohydrologic Techniques

1. Why is it important to assess the magnitude and frequency of flood discharges along rivers? I think it is reasonable to say, considering the climate change since the Holocene, that as far as man is concerned, we have established that most flooding we will experience is going to be meteorological in the near future. That's a generalization based on the likelihood of major geological damming and resultant flooding being a relatively low when you consider our short life span compared to geologic time- straight statistics. But there is every reason to want to understand the entire nature of meteorological flooding- it affects our livelihood, safety, recreational activities, economic situation, etc. Insurance companies and land use planners want to understand things like 100 and 500 year floods, the ones that will cost millions or even billions of dollars, or result in terrible environmental damage (imagine a huge flood event at Turkey Point Nuclear Facility if it was still running!), or loss of life. The average Joe of course, waits for the 5 o'clock news, but that's another story.

Of course, if we did not understand the nature and extent of larger, geologic flooding, we wouldn't know what the possibilities or the probabilities are. Its worth considering Mt. St. Helens, for example. That particular event created lahars in the Toutle River and several other large creeks and rivers to the west and south, all resulting in natural dams. The most notable was the lahar combined with the 0.6 cubic mile of debris flow at the northern base of the mountain and at the head of the Toutle, which began to raise the level of Spirit Lake and some newly formed lakes, a similar situation to what we have seen evidence for on the Deschutes. I don't think anyone had to study other natural geological dams to understand that if they allowed that situation to continue for long on the Toutle, a big flood event was going to occur, perhaps bigger than the original volcanic event. Still, the more we understand geological flooding and damming, the more adept we are at predicting the results of geological events in our lifetime, or even several lifetimes ahead (alas, we are poor dumb creatures, confined to looking in front of our collective noses- shouldn't we be planning to move Portland before the next ice age?). You could probably think of some very important land use changes we should make in order to prepare for the next volcanic eruption, if we could predict where it will be. Understanding geologic flood events is very important in that sense.

Given what we know about the incredible force and magnitude that can result from geological floods, and given that we live in a regions shaped by plate tectonics, volcanic eruptions, varying kinds of volcanic deposition from tephra and ash to lava flows; given the evidence we have seen concerning mass movement of river environments, lava flows, lahars and the damming and eventual spectacular failures and floods that result from that, and given that we know for absolute certainty that these events will occur (only we can't predict WHEN they will occur), we have every reason to try and understand all we can about the history of our spectacular Northwestern landscape.

We also want to consider the role of science. It's our job to know. History is filled with accidental discoveries made while looking for something else. In its most general sense, knowledge is important to have because you never really know when you are going to need it. It is kind of interesting to think of people living (if we don't destroy ourselves first) in Portland some time in the very distant future, in an ice age. If we don't act too stupidly, they will know about the Missoula floods, and leave, in time to maybe witness it from somewhere safe. An interesting scenario, but at least possible. Finally of course, what scientifically minded person isn't fascinated by the stuff we learned about and saw on our field trip. I always get inspired by understanding history, more so when combined with science, and especially when it involves big, exciting, semi-biblical or even full on Noah type events. Science and nature go hand in hand. The study of nature and its immense power is always inspiring, which is worth something in itself.

2. List and discuss the types of techniques that can be used to reconstruct ancient paleofloods particularly as applied to rivers in western and central Oregon. A host of tools and techniques are available. We can evaluate stratigraphy: is there deposition? If so, size of clastics or fines? Are they impacted by movement i.e. rounded? Is there imbrication of bedload? Is there diamicton, sorting? Evidence of scouring or other erosion? Are there paleosols? Aridisols? Is there anything buried in flood deposition that we can carbon date? We can geochemically analyze deposits. We can make descriptions of clastics. We can evaluate recent climatic / biological impacts i.e. plants growing, soils developed? We can look at impact upon plants- rocks imbedded in trees, walking trees. We can look for layers or organic deposit. We can look upstream for relationships between geochemical analyses (granite in Willamette Valley came from Montana, for example). We can evaluate possible volumes and speeds of flow by evaluating physical parameters in the flood location: slope of bed, width of channel, absorptive qualities of channel and floodplain. There is a lot you can do.

Some, most or all of these can be used depending upon the site. These techniques are a set of inter-related ideas that can be used together to recreate little pieces of the paleoflood puzzle. Typically, we use this kind of information from a number of related sites, not just one.

Results from Lab / Field Exercises **

A. Answers to field Trip Reading Questions **

Section 1. Orr and Orr, High Lava Plains 1999

1 Briefly describe the physiographic setting (elevation, physical boundaries, general characteristics) of the High Lava Plains Province of Oregon. The high lava planes is roughly rectangular in shape, bordered on the west by the high Cascades, on the south by the Basin and Range province, to the north by the Blue Mountain Province (includes the Ochocos) and the Columbia River Basalt province. The region is fairly flat, and is mostly about 5000 above sea level, with Newberry Volcano being a major exception, at over 7,000 feet. It is not clearly stated, but the Deschutes River seems to be the western dividing line between the High Lava Plain and the High Cascades. As its name suggests, the high lava plains is a region of volcanic flows that began about 10 million years ago (apparently in the southeastern part of the province) and continued (via

Newberry volcano) until fairly recently. These eruptions may well continue in the future, although I am not sure that some condition will need to change, given what Orr and Orr say about the rhyolitic "blanket" covering the volcano, signifying the end of an eruptive cycle. The emanation of lava flows moved progressively northwest, ending at Newberry crater.

1-2 What fault zone dominate the High Lava Plains? What is its orientation? Brothers Fault, aligned northwest-southeast, dominates the province**.**

1-3 What three major fault/fracture zones converge in the proximity of Newberry Volcano? What is the likelihood of a Newberry Eruption during our field trip? The Brothers fault zone, Green Ridge-Sisters Fault zone and the Walker Rim Fault zone converge at Newberry Volcano. Orr and Orr state that the current existence of the rhyolitic rock at the surface of the volcano suggest that it won't erupt-rhyolitic rocks are typically extruded at the end of an eruptive cycle. Thus, the likelihood of an eruption during our visit was extremely low.

1-4 What is meant by "bimodal" lava composition of the High Lava Plains? List and discuss two types of lavas that have been erupted in the High Lava Plains. Bi (two)- modal means two forms. This is actually a distinctive feature of the High Lava Plains. On the High Lava Plains, basaltic flows predominate. They are lower in silica, and thus less viscous. They emanate from deeper within the earth. Rhyolitic flows, however, are found around the major faults, and they emanate from more shallow locations within the crust. They are higher in silica, and are more viscous. The obsidian flow within the current crater is highest of all in silica. As we have seen in our review of this area, there are many faults in this entire province, due to the clockwise movement of Oregon, which stretched the province, resulting in faults due to an inherent weakness of the earth's crust in this area. These faults, along with a poorly understood situation in the magma below the crust, have caused or rather, allowed these eruptions.

1-5 How does the age of volcanic deposits in southeastern Oregon (e.g. Owyhee uplands) compare to the age of deposits near Newberry? To the southwest, e.g. in the Owyhee uplands, the flows are about 10 million years old. In a fairly uniform fashion, the sources of flow moved northwest, until we reach Newberry, which is brand spanking new in geologic time.

1-6 What is the geologic explanation for the formation of Fort Rock, southeast of Newberry? Orr and Orr described the creation of two other formations similar to Fort Rock, and go on to describe all three of these as the result of hot magma encountering cold groundwater, as the magma rose vertically. They further explain that the breach in one end of Fort Rock was due to the presence of a lake, which eroded the breached end via wave action. The rim is not a lava flow with a crater, it is a ring of debris that settled in a circle around the explosion.

1-7 When were the basalts of Lava Butte (South of Bend) erupted? What Impact did the eruption have on the Deschutes river in that area? Lava Butte is part of an eruptive series of faults and cracks, spreading from Newberry Volcano to Lava Butte and beyond. The butte itself was formed about 6,000 years ago in conjunction with a series of other flows, all of them "parasitic" to Newberry. These flows dammed the Deschutes, creating a lake to the south. Eventually, the river wore through the basalt, and regained at least part of its ancient bed. I could not find the name of the lake formed, but the falls that resulted (they still exist today) when the Deschutes finally broke through the lava dam is Bentham Falls.

1-8 What type of volcano is Newberry? Newberry Volcano is a low profile, composite, shield volcano. That makes sense to me because most of the earlier flows were basaltic (lower in silica, more fluid). Thus, the profile would of course be lower than andesitic or rhyolitic flows. **How did the central Newberry crater (and associated lakes) form?** Like the more famous Mt. Mazama, the Newberry Caldera emptied itself of magma and then collapsed. When it did, it exploded and the caldera, by definition, was the result. **What other famous Oregon volcano experienced similar processes?** Mount Mazama. The result was the now famous Crater Lake caldera.

Section 2 Jenston and Chitwood, 2000- Overview Newberry Volcano

2-1 How long has Newberry Volcano been active? The volcano has been active for about a half million years, to present, and has erupted in basaltic flows many times. These extend over 40 miles from the volcano. These flows reached the Deschutes and Crooked rivers, following their canyons, although Jenson and Chitwood say work is ongoing with regard to details and extent. **What type of volcano is it?** Newberry is a low profile, composite, shield volcano. Interestingly, as the composition of lavas changed from basaltic (less viscous) to andecitic (more viscous) to rhyolitic (very viscous), the decreasing viscosity caused rebuilt cones (atop the previous calderas) to become ever steeper as a result. **What is the chemical composition of lavas associated with newberry?** I think I just explained that.

2-2 How has the Newberry volcanic activity impacted river systems in the region (e.g. Deschutes and Crooked River)? Periodically, lava flows (they must have been more on the basaltic side to flow that far) entered the Deschutes and Crooked Rivers. We did not discuss this in great detail, but by now, having become familiar with that type of process during this course, it seems a foregone conclusion that these flows dammed these rivers each time, creating lakes that drained suddenly as nick points, created by the lava flows, gave way over time. We discussed this situation during our visit to Lava butte, which we know certainly dammed the Deschutes. In fact, geologic damming of the Deschutes by volcanic activity, as well as landslides, is a continually repeated scenario in the geologic and hydrologic history of the river.

2-3 What is the Newberry "caldera"? How did it form? The caldera formed more than once, when the magma chamber inside the volcano emptied, and then collapsed on itself, creating a tremendous explosion which left a large crater. **What topographic features are located in the caldera at present?** There are two lakes- Paulina and East lake, separated by magmatic and other activity that partially refilled the crater after the last caldera explosion. Newberry has continued to form calderas and then refill them, repeatedly. More recently, refilling by magmatic flow has been slow, as Orr and Orr explain. However, enough material has surfaced to create new material since the Holocene era, and a significant ash eruption scared off local Native Americans about 2,000 years ago(re: archeological evidence discussion we had at the peak). As we will probably discuss somewhere below, there is still some continued uplift, due probably to magmatic forces, however much they have been weakened. This is affecting the elevation of the shoreline on the east side of Paulina Lake.

2-4 How far south and north of Bend does the Newberry Volcano extend? That's kind of a confusing question, because it depends on whether you consider the volcano proper or its lava flows as the entire volcano. Jensen and Chitwood show the vocano extending to within about 8 miles south of Bend, at its northernmost point, to about 45 miles south of bend at is southern end. The lava flows extend over Bend (but just barely, considering east to west) and all the way up beyond Redmond, even continuing as far north as Madras, within the Deschutes River Canyon. **Is Bend part of Newberry Volcano?** No, but if you were making a disaster movie, you could make Bend the star attraction as a victim of a basalt flow.

2-5 In chronological order, briefly list the dates and names of known eruptions at Newberry. Actually, it might be more correct to label past eruptive events as "episodes" since Jensen and Chitwood describe each of them as typically a series of events centered around a specific time. It's also worth remembering that Jensen and Chitwood describe Newberry as having been active for half a million years. For a lesser known, less conspicuous volcano, Newberry has had a substantial impact on the surrounding area, to say the least.

Known eruptions:
South Obsidian Eruptive Episode- 12,000 years ago.

East Rim Eruptive Episodes- 11,200 years ago.

Interlake Eruptive Episode Episode- 7300 years ago, including
  Interlake Flow
  Crater Flow
  Game Hut Flow
  Central Pumice Cone eruption
  All over a period of about 200 years

Northwest Rift Eruptive Episode- 7,000 years ago
  Over a dozen lava flows, w/assoc. cinder and spatter cones over about 50 years.

Big Lake Eruptive Episode- 3500 years ago
  Obsidian flows and assoc pumic deposits

Big Obsidian Eruptive Episode 1460 years ago
  Newberry Pumice (air fall tephra)
  Paulina lake ashflow
  Big Obsidian Flow (last eruption- about 1300 years ago)

Section 3. Orr and Orr, 1999- Overview of Deschutes-Columbia Plateau

3-1 What are the major rivers that drain the Deschutes-Columbia Plateau region. What is the dominant type of bedrock material that characterizes the region? The Dominant bedrock is of course, Columbia River Basalt. The Columbia River, 3rd largest in America is the largest waterway in the region. The Deschutes, John Day and Umatilla Rivers are the major tributaries of the Columbia Plateau in Oregon.

3-2 Where does the Deschutes river drain from and to? How long is it? How does it relate to the Columbia River? The Deschutes headwaters are the small, eastward flowing streams at the base of Mt. Bachelor. The Deschutes flows north, for 250 miles, until it joins the Columbia River at the Oregon border. Thus, it is a tributary to the Columbia.

3-3 What is the significance of the Columbia River Basalt (CRB) group in this region? When were the CRB's erupted? Over how long of a period were they erupted? The CRB's completely dominate the region. They comprise the second largest basalt flow in the world. In Yakima and Pasco, they are up to 15,000 feet thick. They are thinner in the region that is located within Oregon. The CRB's were erupted from 17 to 6 million years ago in a succession of long events, the largest (Grande Ronde series) of which makes up over 85% of the volume of the entire set of flows. Typically, flows occurred about every 35,000 years.

3-4 Describe the geographic extent of the Columbia River Basalts in terms of Washington and Oregon? How far north do they extend? How far south? How far east? How far west? The overall size of the flows would cover approximately the area of the present state of Washington. The region covers all of SE Washington State, much of central Washington, as far north as the Okonogans, much of north central and northeast Oregon, and a part of it covers the western edge of Idaho. The entire Columbia Gorge is carved into CRB's, all the way to the Pacific. With the exception of the Columbia gorge, which cuts through the

Cascades, the western boundary of the CRB's was formed by ancient Cascade volcanoes, while the northern boundary is roughly the Okonogans of Washington, to the east, the Clearwater mountains of Idaho stopped progress of the flows. The southern boundary is not well explained in our literature- the CRB's extended (Imnaha flows) from within the Blue Mountain province at one point. Details aside, this series of events was long and monumental, dominates the region to the point of obscuring underlying formations which are still not well understood, and impacts us today on a grand scale.

3-5 Approximately how many individual lava flows have been identified in the Columbia River Basalt Group? Approximately how often did the eruptions take place? On average the eruptions occurred about every 35,000 years, although more detailed information by Orr and Orr shows variations from one flow/40,0000 years to one every 7,000 years. There were 311 flows, according to Orr and Orr.

3-6 Where is the source region for the Columbia River Basalts? Were these erupted by volcanic mountains? Explain your answer. The source of the CRB's moved over time. Generally speaking, we can say they emanated from fissures in the region where Idaho, Washington and Oregon meet today. These were volcanic flows, but the low viscosity precluded building of mountainous structures. Instead, the flows came out of fissures and moved in all directions, though by far the predominant direction was westward. Interestingly, Orr and Orr describe some of the flows as having moved up to 30 miles per hour, certainly a rate that suggests a viscosity that would not cause building upward into mountainous forms.

3-7 How do the Clarno and John Day formations compare to the CRB's? Are they older or younger? Are they also composed of basalts? What are they composed of? What type of rock material? The Clarno and John Day formations are older than the CRB's. After all, they are overlain by the CRB's. Both of these formations are volcanic in origin, and they are complicated mixtures that resulted from volcanic eruption and geomorphic processes upon the products of those eruptions. The Clarno (55-38 m.y. ago) is made up of tuffaceous sediments (tuff washes away, depositied, becomes rock), lava flows, lahars, lake and river deposits, paleosols (old soils, turned into rock). The John Day (38-25 m.y. ago) is made of ignimbrites (welded tuff) and volcanoclastics (broken up rocks from various other volcanic events) as well as fluvial (river) and lacustrine (lake) deposition of the parent material. In other words, both formations are made of volcanic products acted upon over time. The result is that both formations, especially the John Day, are weaker than CRB's. The result has been faster rates of erosion once the CRB's were eroded away, in the lower-middle Deschutes. This area was uplifted more quickly than the surrounding CRB's, thus causing the CRB's in this area to be eroded long ago, exposing the John Day and Clarno formations.

3-9 How did the Pleistocene ice ages and Missoula floods impact the Columbia Plateau? What types of deposits and landforms record the history of the Missoula floods?

Portions of the Columbia Plateau in Eastern Washington and throughout the Columbia Gorge, including portions of tributaries such as the Deschutes and John Day rivers were scoured by the release of something along the order of 9 cubic miles per hour of flood water, suspended load, bed load, and glacial ice containing glacial erratics. This flood created the channeled scablands of Eastern Washington, meaning that all of the glacial loess deposited during the Pleistocene Ice Age, was scoured away down to the CRB bedrock which itself was further eroded by the Missoula Floods. Major waterfalls, dwarfing for example, Niagara Falls, existed for the approximately two weeks during each of these repeated floods, and these tore away tons of bedrock. An excellent example is Frenchmen's Cataract, located just north of I-90 where it crosses the Columbia River, in Washington State.

The water flow from the Missoula Floods was so deep, and so fast (up to 300+ meters, 40-90 mph depending on extent of restriction) that it created hydraulic conditions rarely seen on our planet. The landforms that resulted from this are the channeled scablands and a scoured Columbia Gorge. As we drove along the rim of the gorge, the depth and extent of the floods was visually obvious- CRB outcrops were visible up to about 300 m in the narrower parts of the gorge. Above the reach of the flood, topsoil has had time to develop- it was not washed away in the floods, and thus covers the underlying basalt. Below the depth of the floodwaters, there is no topsoil.

Scouring of soil and bedrock are one legacy of the Missoula Floods (the exact number isn't established, but there were probably around 90 Missoula Floods). There was also deposition of bedload, suspended load and glacial erratics in various places throughout the flood, at different times for different reasons. Deposition of gravels and boulders occurred even at the highest levels of flooding, due to eddies and other slowing of the current, caused by geomorphology existing during the time of the flood. For example, Rocky Butte, northeast of Portland, and in the middle of the Portland Plain, was about 90 feet higher than the flood waters. This existing natural barrier caused enough of a slowdown in the downstream flood current, that it formed Alameda ridge, which is actually a gravel bar (2-3" gravels). Today, it is about 240 feet high and unnoticeable as a gravel bar except to the discerning eye, because it is so monumentally large for a gravel bar.

Deposition of gravels and fines occurred throughout the flood area as high water receded. So for example, portions of the Walla Walla river valley contain multiple layers of fine sediment deposited by the floodwaters there, as they receded. Velocity would obviously have been slow, resembling perhaps even a lacustrine environment, though it would have been relatively short lived.

At various places along the flood route in the Columbia River Gorge proper, events referred to as "slopover" occurred as the floodwaters became deeper than lowpoints in the surrounding gorge walls. At both Petersburg Divide and Fairbanks Divide, floodwaters crested the gorge at these low points, and then spilled into what is now called Fifteenmile Creek. The floodwaters had sufficient velocity that they carried gravels at these locations, and as the waters crested, and thus lost some velocity, gravels dropped out and formed large, deep depositional formations.

If you travel up Three Mile Creek, south of The Dalles, you can find deposition of very fine particulates as the flood waters moved into tributaries of the Columbia. We did not discuss this in detail during our several stops along Three Mile Creek as we traveled briefly south on highway 197, but the current must have had reason to slow there in order for such fine particulates to drop out. The same situation is found along all the tributaries of the Columbia Gorge.

As you can see, the result on landforms in general was to scour the existing topsoil and then bedrock in the path of the flood, from its exit from Glacial Lake Missoula, all the way to the Pacific Ocean. Some deposition occurred where the current was slowed by existing geomorphology and deposition occurred as floodwaters receded and slowed their velocity. Interestingly, only an estimated 1% of the load in the floodwaters was deposited on land. The rest of it forms a debris deposit something like 700 miles out into the Pacific Ocean.

B. Surficial Mapping Data Log Summary (extra credit) **

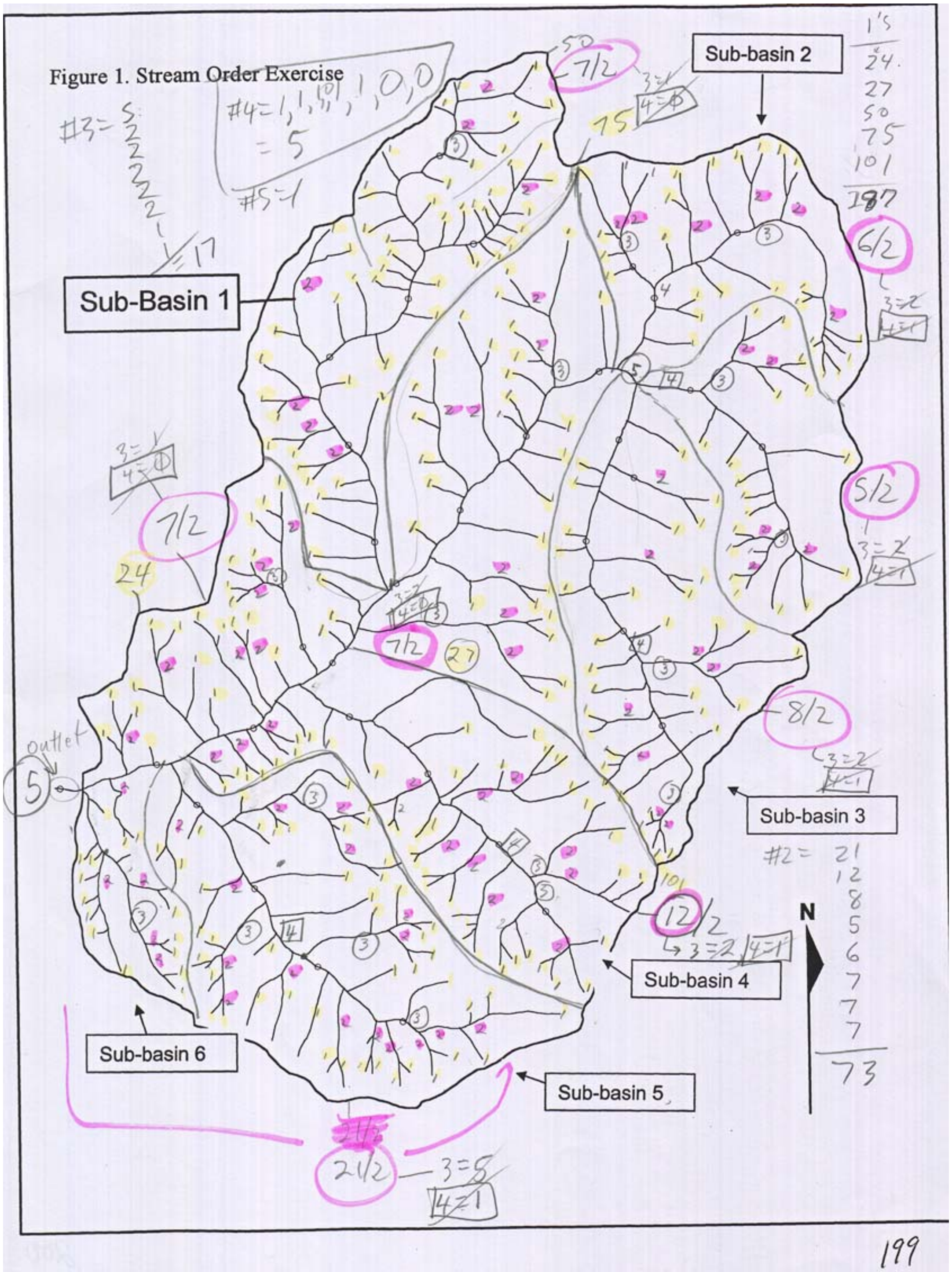
C. Stream Ordering Exercise (p197-199 field guide) ****

1. Label the drainage boundary- see copied map.

2. Compare the map to the drainage patterns shown on Fig 5.2 A, p. 32 field manual. This is a zone 1, production basin.

3. Draw divides around the basins- see copied map.

4. Label all the stream orders- see copied map.



5. **Highest stream order** 5

Total 1st order segments 287

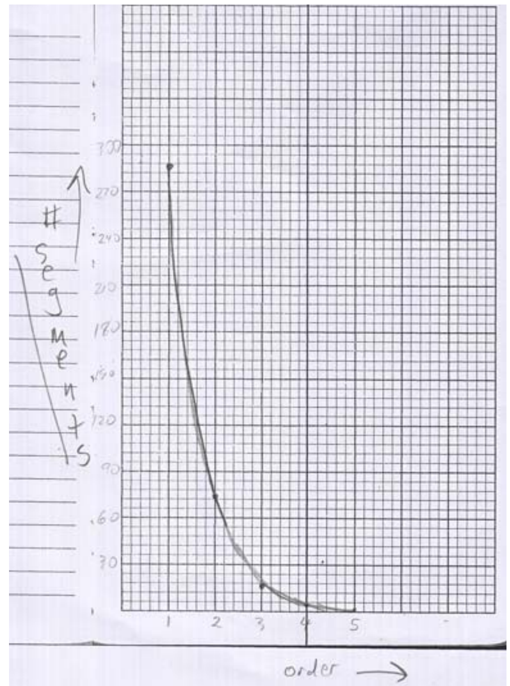
Total 2nd order segments 73

Total 3rd order segments 17

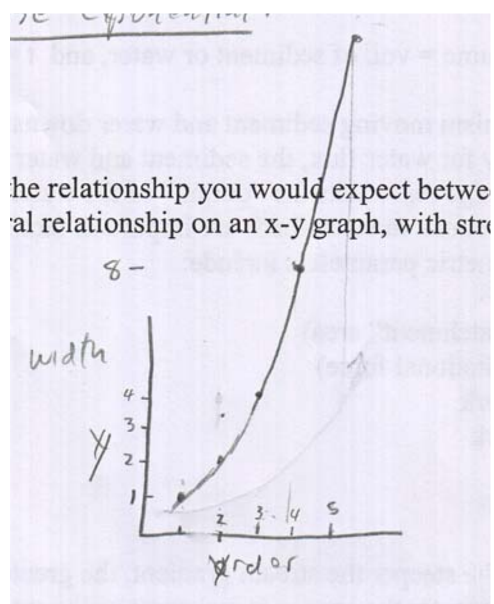
Total 4th order segments 5

Total 5th order segments 1

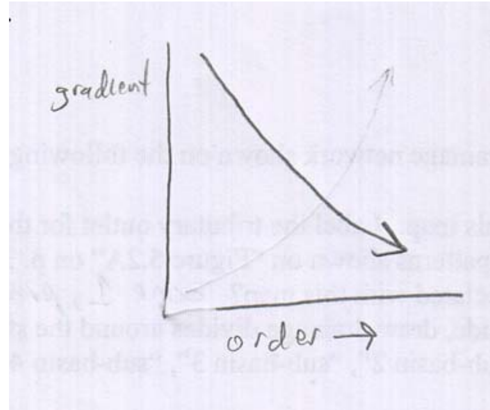
What is the general relationship between stream order and the number of stream segments in the order? Plot the general relationship on an x-y graph, with stream orderon on the x-axis, and number of segments on the y axis. Generally speaking, it is the reverse of an exponential graph. As order increases, the number of segments decreases by a root.



Hypothesize the relationship you would expect between stream order and stream channel width. Plot the general relationship on an x-y graph, with stream order on the x-axis and channel width on the y-axis. Generally, I think you would expect channel width to double every time you increase stream order.



Hypothesize the relationship you would expect between stream order and channel gradient. Plot the general relationship on an x-y graph, with stream order on the x-axis and channel gradient on the y-axis. I think higher stream order yields less and less gradient. Higher order streams have a lot of deposition from the lower order streams, and they have to move that. So, you will get a build up. Every example I think of, relating to rivers I have seen, seems to prove this generally.



If the bedrock underlying a given watershed was very porous and permeable (i.e. spongelike), would you expect the number of stream channel segments to increase, decrease or stay the same? If all other things were held equal, you would expect less channels. Compare an asphalt watershed, where everything runs off, to really sandy watershed, which absorbs a lot of water. However, the watershed would probably be more steady- the absorbed water eventually makes its way to some outlet, such as the case in the Deschutes, which has a spongelike quality over much of the drainage.

D. Answers to Fluvial Hydrology Problem Set (201 of field guide) **

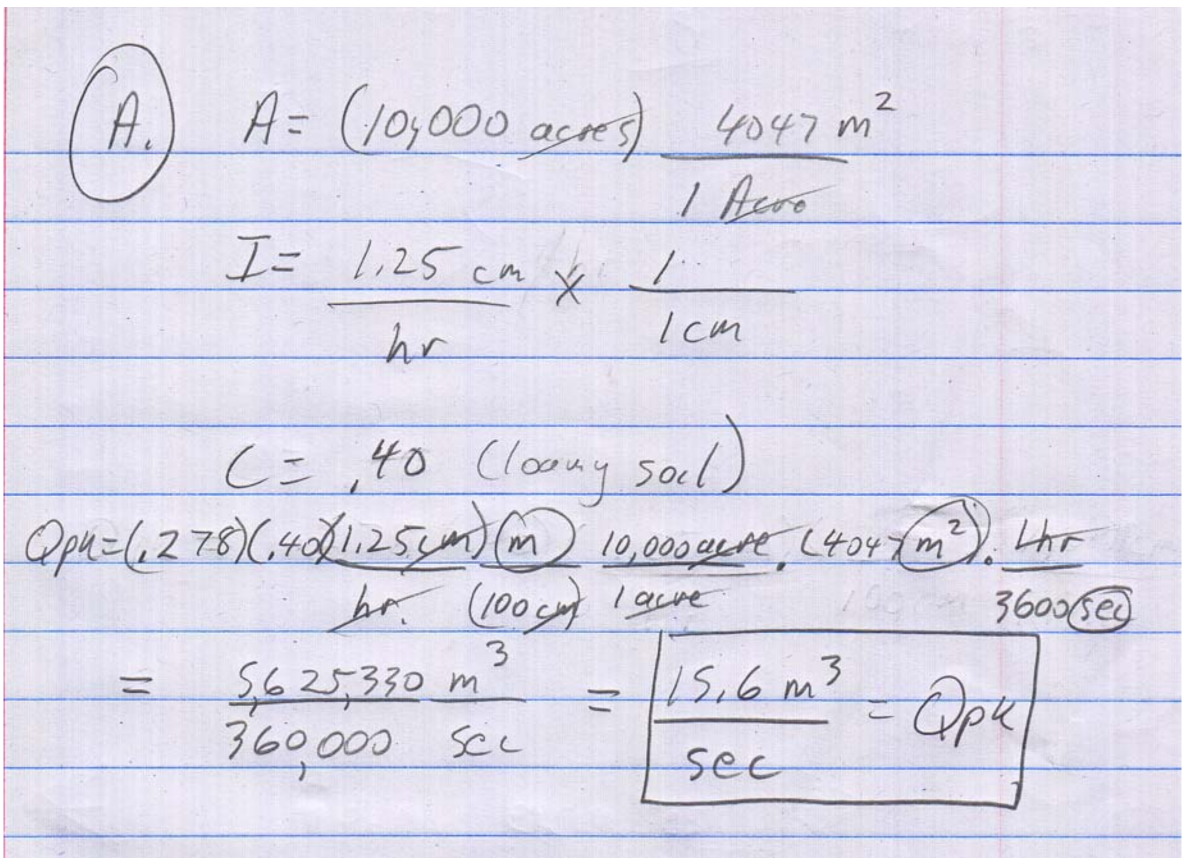
Using the equation lists on p 35-37 of your field guide, and the unit conversion charts on p 123-130, solve the following problems. Show all of your math work and calculations!

1. The rational runoff method predicts peak runoff rates (discharge = vol / time) from data on rainfall intensity (i.e. rainfall into drainage basin) and watershed characteristics (e.g. underlying bedrock type and infiltration capacity). The governing equation is:

$$Qpk = 0.278CIA$$

Where Qpk = peak discharge of drainage basin in m^3/sec, I = rainfall intensity in mm/hr, C = infiltration factor of watershed (asphalt/concrete = 0.80, thin soil over bedrock = 0.40), and A = drainage basin area in km^2.

A. Determine the peak discharge (in cubic meters per second) for a drainage basin experiencing a rainfall event with the following characteristics: drainage area = 10,000 acres, rainfall intensity = 1.25 cm/hr, and substrate = loamy soil over sandstone. Show all your work.



B. If a drainage basin has an area of 175 km^2 and experiences a 30 mm/ hr rainfall event, with a 500 m^3 / sec peak discharge, calculate the infiltration factor for the watershed. Show all of your work. Based on your answer, is this watershed likely rural/forest or highly urbanized? Explain your reasoning.

$Q_{pk} = \frac{500\ m^3}{sec} =$ $I = \frac{30\ mm}{hr.}$ $A = 175\ km^2$

$Q_{pk} = .278\ C\ I\ A$

$\frac{Q_{pk}}{.278 IA} = C$ $\frac{500}{(.278)(30)(175)} = \frac{500}{1459.5}$

(B) $Q_{pk} = .278 CIA$ C-no units, I - mm/hr → 30

A - km^2 = 175

$Q_{pk} = .278 CIA$

$\frac{Q_{pk}}{.278 IA} = C = \frac{500 m^3}{sec} \cdot \frac{1}{(.278)(175)(30)}$

C = .34 (Taylor left out the conversion units for C)

if C = .34 ≃ likely rural forest.

C. If 30% of a forested, 1000 km2 watershed is urbanized, calculate he anticipated peak runoff associated with a 0.5 in/hr rainfall event.

(C) $Q_{pk} = Q_F + Q_u \qquad I = \frac{0.5\,in}{hr}$

$$Q_{pk} = \underbrace{[.278(I)] \cdot C_F A_F}_{Q_F} + \underbrace{[.278(I)] \cdot C_u A_u}_{Q_u}$$

$$\left[(.278)\left(\frac{0.5\,in}{hr}\right)\left(\frac{2.54\,cm}{1\,in}\right)\left(\frac{m}{100\,cm}\right)\left(\frac{1\,hr}{3600\,sec}\right)\right]$$

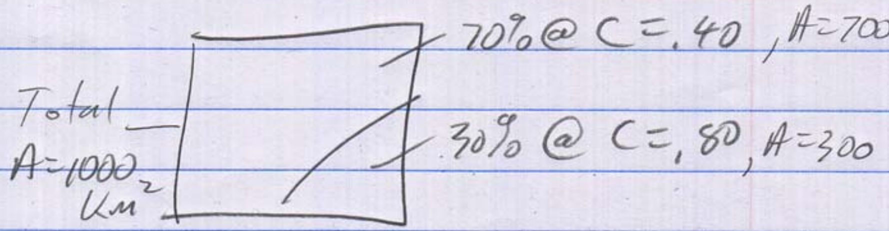
$$\boxed{\frac{9.81 \times 10^{-7}\,m}{sec}}$$

$$\left(\frac{9.81 \times 10^{-7}\,m}{sec}\right)(.40)\left(\frac{700\,km^2}{1}\right)\left(\frac{10^6\,m^2}{1\,km^2}\right) = \boxed{274.68}$$

$+$

$$\left(\frac{9.81 \times 10^{-7}\,m}{sec}\right)(.80)\left(\frac{300\,km^2}{1}\right)\left(\frac{10^6\,m^2}{km^2}\right) = \boxed{\frac{235.37\,m^3}{sec}\ \text{urban}}$$

$$\boxed{Q_{pk} = \frac{510.05\,m^3}{sec}}$$



2. If a river channel has a discharge of 5 ft3/sec and a cross-sectional area of 5 m2, calculate the average velocity of the river in m/sec. Show all your work.

(2) $Q_{pk} = \frac{5\ ft^3}{sec}$ and x-sect = $5 m^2$

~~calculate~~

calculate velocity

$Q_{pk} = V \cdot A$, $A = 5 m^2$, $V = ?$

$\frac{Q_{pk}}{A} = V$ $\quad \left[\frac{5\ ft^3}{sec}\right] \cdot \left[\frac{1}{5 m^2}\right] \cdot \left(\frac{0.02832 m^3}{1 ft^3}\right) = V$

$Q_{pk} = \frac{(5)(0.02832)\ m}{sec} = \boxed{\frac{.1416\ m}{sec}}$ ANSW

3. Empirical data show tha hypothetical watersheds in the western Cascades have peak flood discharges every 2-3 years as described by the following equation:

Q2.33 = 34.5A0.93

Where Q = peak discharge in ft3/sec and A = drainage area of a given basin in acres. Calculate the expected peak discharge for a drainage basin with an area of 125 km2. Show all of your work.

(3) $Q_{2.33} = 34.5A^{0.93}$

Generally: $Q_x = aA^b$ x = interval

a = coefficient

b = exponent

$A = 125\ km^2$, $Q_{2.33}$ is in ft^3/sec A = acres

$$\left(\frac{125\ km^2}{1} \cdot \frac{10^6\ m^2}{1\ km^2} \cdot \frac{(3.28)^2\ ft^2}{1\ m^2}\right)^{0.93} \cdot \left(\frac{34.5}{1}\right)$$

↖ A ↗ No - get into acres

$$\left[(125)(10^6)(3.28)^2\left(\frac{1\ acre}{43560\ ft^2}\right)\right]^{0.93} (34.5) = Q_{pk}$$

↓ 10.76

$$\left(\frac{125 \cdot 10^6 \cdot 10.76}{43560}\right)^{0.93} (34.5) =$$

$$= (30877)^{0.93} (34.5)$$

$$(14974.8)(34.5) = 516{,}603\ ft^3/sec$$

E. Review Day 1 /Preview Day 2 Concepts (p 203-204 field guide) **

1. Using your class notes, write and explain the following equations that pertain to fluvial dynamics (show all unit algebra in metric units)

A. Force (according to Newtons 2nd Law)

Measured in Newtons N Force = ma mass x acceleration. Measured in newtons, 1 kg m/sec^2

Water has force when it is moving, and this can be measured in Newtons.

B. Work- in watts. The rate at which work is done when an object is moved at a sped of one meter per second against a force of one Newton.

W = watt = J/sec or Joules per second.

C. Weight- in newtons, N. Force of attraction of the earth due to gravity is weight, in N.

D. Density measured in mass/vol typically g/cm^3 or kg/m^3 Density is the amount of mass found in a given volume of something. Typically densities are converted to the same volumes for ease of comparison.

E. Potential Energy

F. Kinetic Energy

2. Using your class notes, write and explain the following equations that pertain to river hydrology (show algebra units in metric)

A. Flow Velocity

The velocity or speed at which flow occurs in a stream. Q, discharge = Velocity x Area cross section

B. discharge (according to continuity equation)

Q = VA. Discharge in m3/sec = velocity in m/sec x Area of channel in m2. In other words the discharge volume is a cubic measurement per second calculated by estimating the cross sectional area of a stream and multiplying by the actual velocity at which the water in the stream is moving.

C. Wetted Perimeter

The bottom of a creek forms an arc, or approximation of one. This is a perimeter where the stream touches the earth, from bank to bank. Used in Manning's equation to calculate stream velocity. The unit is in meters.

D. Mannings Equation

Used to calculate stream velocity

$V = \frac{R^{2/3}S^{1/2}}{n}$ **V = velocity in m/s R = the hydraulic radius** → **R = A/P**

A = channel area m^2
Cross section
P = wetted perimeter in m
The length of the arc shape made by the stream from side to side in the steam bed.

S = slope n= roughness

E. Stream Power

The kinetic energy available for work by a stream

$\Omega = ðQs$ in watts ð = specific weight of H_2O 9800 N/m^3 Q = discharge in m3/sec s = slope (no units)

F. Roughness (Manning's n)

n is a coefficient of roughness, much like the coefficient of friction for solid objects moving over a surface. The roughness or smoothness of the stream bed will have an effect on velocity that can be simulated using a value for n.

3. Review Questions from Day 1

A. List and briefly define the 5 agents of transport at the Earth's surface (agents of sediment transport). 1. Water- carries fine sediments, can carry larger rocks, even boulders when flow is very high. 2.Ice- glaciers flow in "slow motion" (compared to water), and can move very large to very fine regolith. Also ice freezes and melts, widening cracks into which water flowed and then froze, eventually breaking off pieces of rock. 3. /gravity- on a slope, as water and/or ice carry away rock or regolith below, deposits above will fall downward, from small to gigantic amounts (rock slides, debris flow, etc), depending on various conditions such as how much water is in the soil or other deposit, how steep, also may be combined with tectonic/earthquake events. 4.Wind- can move fines, also, these can act like sandpaper on other deposits or formations, and deposit the eroded material elsewhere. Another example is loess- from sublimation of glacial ice with fines suspended within it. 5.Animals and plants- Roots can literally split rock, just as ice expansion will do. Depending on geomorphology/slope this can result in alluvial deposit. Animals digging or even walking on a steep enough slope will cause alluvial action. Earthquake events can move sediment in conjunction with other agents, so I'm not sure where it fits, but they certainly play a part in sediment transport sometimes.

B. What are the 4 criteria necessary to systematically analyze the geomorphic character of the landscape (forms basis of surficial mapping criteria)?
Landform, material, age, process. Landform- what is the current shape- slope, cliff, plain, bench, previous slump, etc? Material- what is it made of- bedrock/regolith, sediment, metamorphic, type of parent material, etc. ? Age- how long has it been here, and exposed to various geomorphic processes? Process- what is and has happened to it- uplifting, sinking, water/ice/gravitational/plant/animal/ erosion, etc.

C. what are the two primary controlling factors that allow rivers to perform geomorphic work? Briefly explain. water and slope. Water has mass, and will of course, flow downhill over whatever the existing gradient is, due to the force of gravity acting upon the water. Fluidity and the special properties of water add to this effect, of course. Zero gradient (dam) or very low gradient, yields deposition. High gradient yields eriosion due to the force of the water along with whatever colluvium it picks up- sort of a snowballing effect, depending on details of the situation.

D. Define the following terms as related to surficial materials.

<u>Regolith</u>- broken up parent material- not solid rock anymore.

<u>Bedrock</u>- solid rock

<u>Alluvium</u>- wet erosion deposits

<u>Colluvium</u>- dry erosion deposits.

<u>Till</u>- glacial mixing and grinding of underlying material. Often deposited in moraines.
<u>Diamicton</u>- mix of varying sizes of colluvium or alluvium. Typical of glacial deposit.

<u>Cross stratification</u>- Various layers of deposits laid down in lenticular pattern, for example dunes laid atop one another over time.

<u>Clast imbrication</u>- Bernoulli's principle (or part of it) tells us that as water passes over a rock, the downstream end of it is lifted. Thus, imbricated rocks (more especially cobbles) are seen pointing downstream, with the downstream end lifted and placed upon the upstream end of the next rock in line downstream. Even very large boulders, involved in large flood events, can be imbricated.

G. Whiskey Dick Exercises (extra credit) **

H. Buckskin Mary Exercise (Flood Recurrence Intervals (p211-212 field guide) **

Read over the notes on flood periodicity (i.e. "recurrence interval") as presented on p 14, p 39-40, p 45 and p 66 of the field guide.

1. A total of 60 years of river discharge data were collected for a hypothetical river. The peak discharges for each year were identified and tabulated (herein referred to as "Qp"). The data were ranked from 1=highest Qp to 60 = lowest Qp for the 60 year period. A subset of the data below were selected from the 60 year record.

A.

data below were selected from the 60-year record.

Qp (cu. m /sec)	Rank	RI	Prob. = 1/RI
1300	16	61/16 = 3.81	.26 = 26%
500	53	61/53 1.15	.87
1100	23	61/23 2.65	.38
1700	6	10.16	.098
2200	2	30.5	.033
2000	3	20.3	.049
100	60	1.02	.98
300	57	1.07	.93
800	39	1.56	.64
1500	10	6.1	.16

$RI = \frac{n+1}{m}$

n = total # events or yrs.

m = Rank of event 1 = largest

Qp = Max disch (L^3/t)

Qp daily - max daily

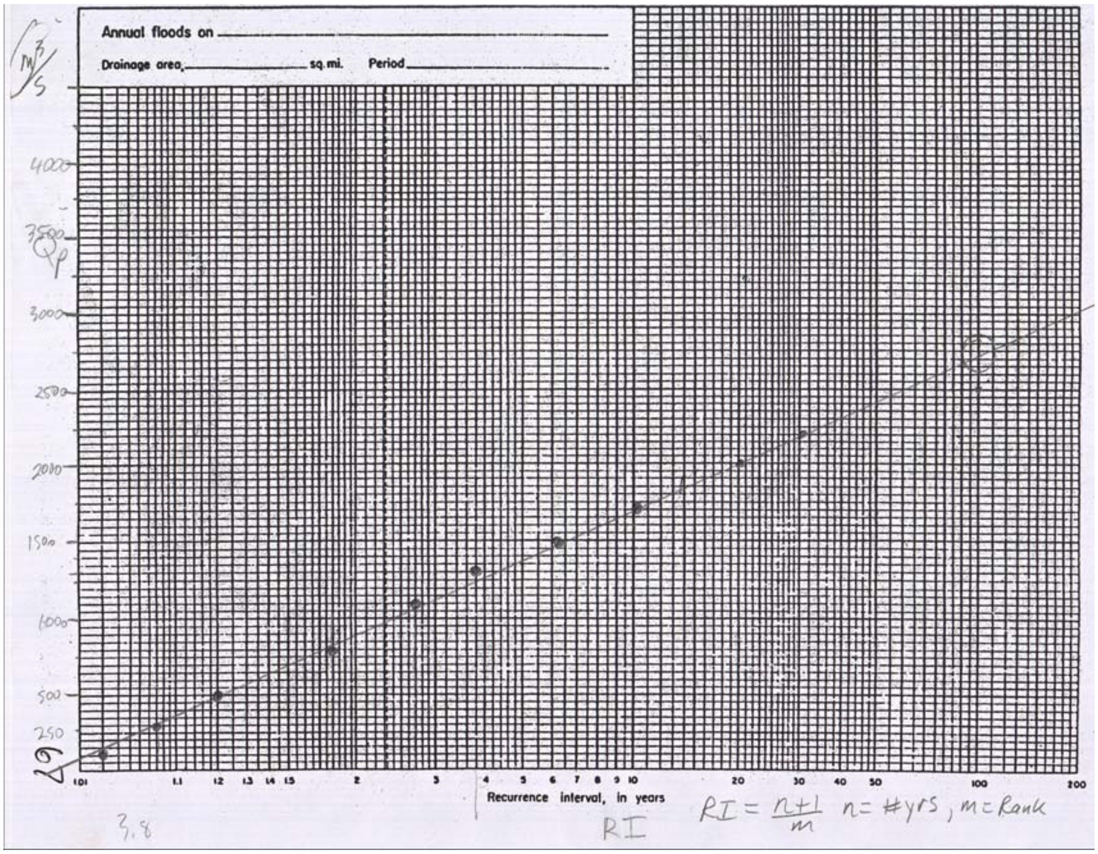
Qp annual

Calculate RI for each of the discharges. See above chart.

B. Calculate the probability of occurrence for each of the above datum (p=1/RI), See above chart.

C. Plot the recurrence interval –Qp data on the Gumbel probability graph on p 69 of the field guide. RI is on the x axis, put Qp on the y axis. Use a y-axis scale of 10 tics = 500 cu. m/sec

D. Draw a best fit line through the data, project the line to estimate Qp-100 (i.e. the anticipated discharge necessary for a 100 year flood. Qp-100 is approximately 2700 cu.m/sec.

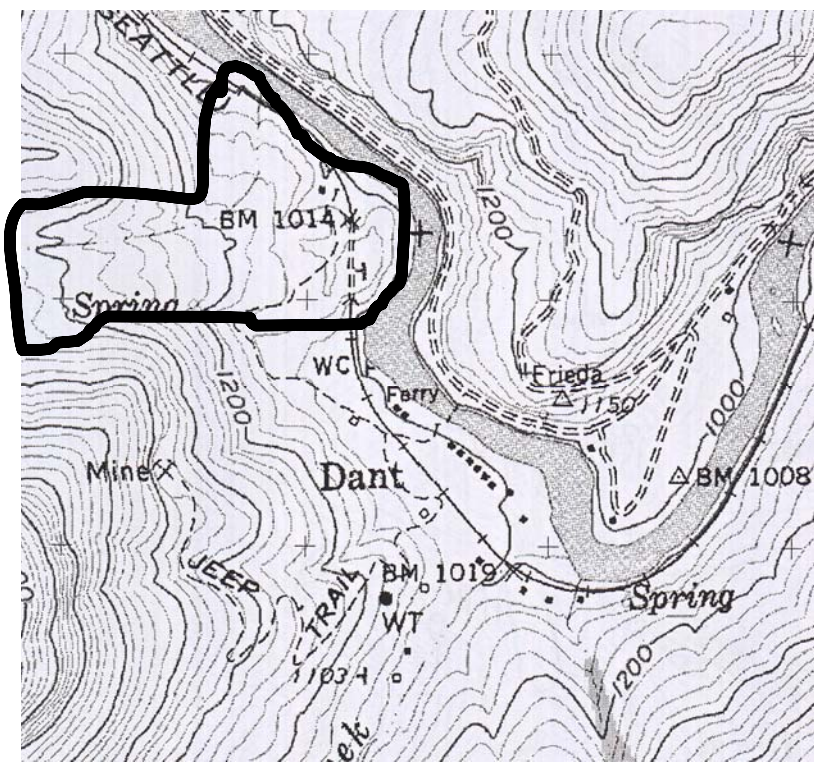


E. Examine the graph you have created. Comment on the relationship between the frequency of small-scale floods vs. large scale floods. Which ones happen more often? How does the frequency of occurrence relate to the probability that a flood of a given magnitude will occur in a given year? We don't actually know, from our data, what constitutes a flood in this hypothetical river (Did peak discharge equal a flood?). Nevertheless, we can say with certainty that lower flows are more frequent than higher flows. Using plain logic, a small flood is a lower flow than a big flood, thus less frequent. Small scale floods happen more often than large scale floods. The actual discharge each year, gathered as data over a long time, extended by paleoflood history, gives us a large enough value of n to generate an actual bell curve, simply showing the number of times and value of each flood occurrence (you have to do a few simple manipulations to make the curve, but the basic idea holds). You could plot this information as a bell curve, show the distance to two standard deviations away from the mean (the confidence interval) and generate the same information you show on the Gumbel plot. This is just straight statistics. The use of standard deviation and other typical statistics calculations to establish a 90% confidence interval, means most of the time, our estimate will be correct. We use the calculation for RI you gave us along with the Gumbel graph, to make the probability into a straight line, making it easier to hypothesize numerically about future flood events. So, as RI increases, its likelihood of being large decreases- it happens less often, and is likely to continue to happen less often. Another way of saying this is that "whatever happened in the past, most often, is likely to happen in the future" dam, etc).

2. Examine the hillslope adjacent to Buckskin Mary Campground on river right. Compare the hillslope deposits and shape to the mass wasting diagram on p 113 of the field guide. Identify the dominant processes responsible for the colluvial deposits that you observe.

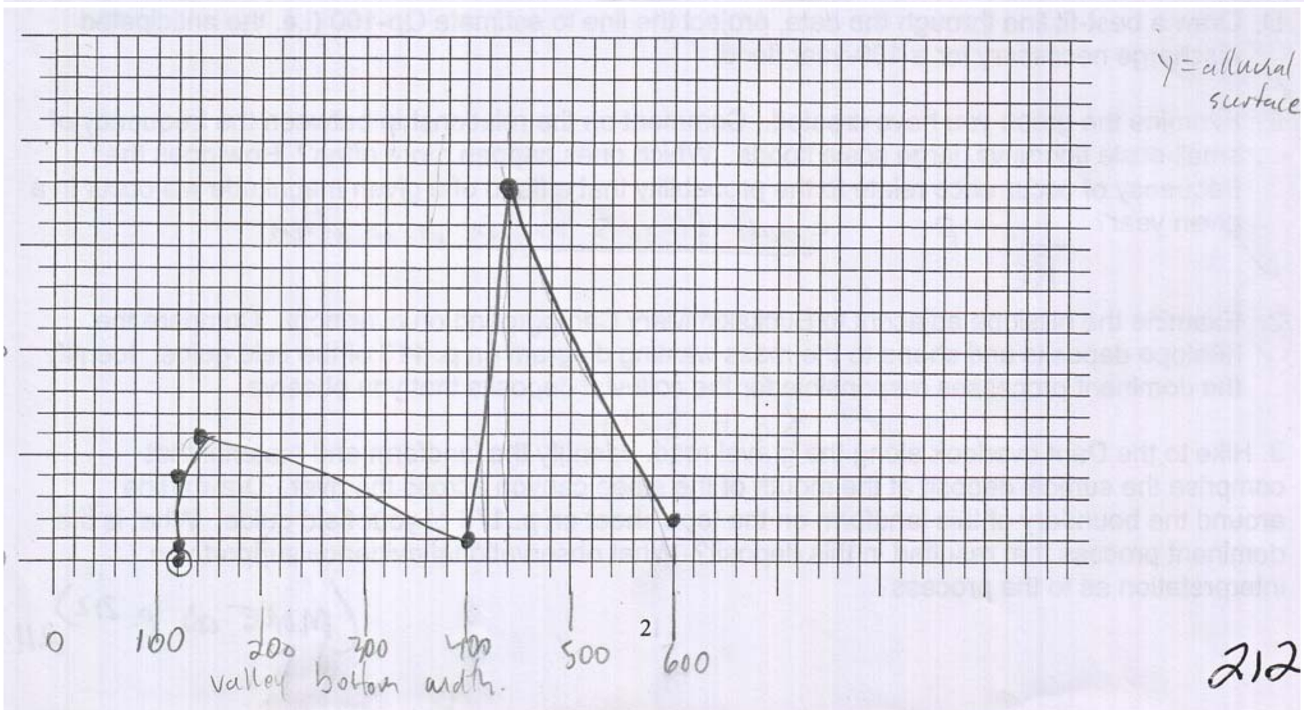
I looked back at photos and my notes. I wrote that the mass wasting on river right, at Buckskin Mary campground, was rockfall. This makes sense, looking at the topographic map. On river right, there are a lot of cliffs.

3. Hike to the Dant overlook along the gravel road. Identify the landform and material that comprise the surficial deposit at the mouth of the steep canyon across the river. Draw a line around the boundary of this landform on the topo sheet on p 173 of your field guide. What is the dominant process that resulted in this deposit? What observational evidence support your interpretation as to the process. We are looking at Clarno formation, we know that from our location and studies so far. The material is colluvium- from far away you can see the rocks are angular. Clarno is bedrock, ugly, but bedrock. Thinking about processes here, we see Clarno as steep colluvial hillsides or cliffs. Hillsides form as the cliffs erode. That's not what we see here. The land is hummocky, and has a fairly shallow, uneven slope. All the shallow slopes near the river so far seem to have been old terraces. This is not a terrace- not flat. Besides, we are not at a wide area, where terraces usually form. Looking at the map, the contour lines suggest irregular spread of materials, not the even spacing we see elsewhere. There is a rapid formed in the river at the bottom of this formation. Also, on the map, at the mouth of a canyon or drainage, you might expect to see an alluvial fan, but I haven't noticed any of those around here, especially not in a narrow part of the valley. This does not look like a differentially eroded outcrop either. We have seen in the literature that the John Day and Clarno are given to landslides.This was a landslide.



4. Using the data presented on p 235, plot an X-Y graph of alluvial surface area (y-axis) vs. valley-bottom width (x-axis) To derive the data read the graphs on p 235 and fill in the table below for the river—mile positions listed. After you fill out the table, plot the graph in the space below. Answer the summary questions.

River Mile	Valley-Bottom Width (meters)	Alluvial Surface Area (hectares)
100	120	0
90	120	0
84	600	40
81	120	12
79	400	2
73	440	36
67	~~360~~ 120	1
50	120	8



A. From your graph, describe the relationship on the Deschutes between volume of alluvial deposits in storage and valley-bottom width. At what valley bottom localities would you most likely find a flood record that would preserve paleoflood stage indicators. Frame your answers in the context of valley width, transport energy, stream power and sediment-transport efficiency.

There is no straightline relationship, only a generality. It is possible that difficulties using the small sized charts (they are hard to read accurately, even with much time spent, using a clear ruler) resulted in some errors in my table, and thus, my graph. Generally, and as common sense would dictate, wider valley bottom locations tend to have more alluvium deposits. Paleoflood indicators are alluvium deposited during floods in the past, beyond historical record. These indicators will be, typically, deposited in wider areas, where stream power is not focused- meaning there will be less sediment transport energy. Less transport energy means that whatever the water was carrying before it encountered the wider, energy dissipating area, will begin to settle out. Thus, if you want to look for paleoflood records, look in the wider areas of the river valley bottom.

K. Deschutes River – Applied field Problems Exercise (217-222) **

Part I - Paulina Lake Geomorphology and Hydrology

We will be making two field stops at Paulina Lake one on the eastern side of the lake at Little Cone Camp Ground and one on the western side where the resort access road crosses the Paulina Creek outlet (refer to base map on p 161 of the field guide).

A. At Little Cone Campground, observe the present day lake level and compare it to the flat topographic bench upon which the campground is located. Are these two features at equal elevation of different? If different, measure/estimate the relief (meters) between the modern lake level and the campground bench. The water level is about 2 meters lower than the bench.

B. Observe the present-day wave action of Paulina Lake, as waves approach shore. Based on your coastal experience with water waves, are they erosional of depositional in nature? The waves, as usual, are erosional. You can see the exposed face of the bench is being slowly undercut by wave action.

C. What type of vegetation is growing on the bench upon which the campground is located? Typical Central Oregon- Ponderosa and Lodgepole with typically shrub understory.

D. Using the surficial mapping protocol listed on p 116 of the field guide, identify the landform upon which the campground is located. It appears to be an apron. Its old deposit from the volcanic eruptions, probably from the little crater eruption, since its right next to it.

E. At Paulina Lake Outlet, observe the present day lake level and compare it to the flat areas surrounding the lake shore. Are these two features at equal elevation of different? The outlet and the water level are the same elevation.

F. What type of vegetation is growing on the flat areas surrounding the lake shore at Paulina Outlet? Grasses.

G. Considering the mechanics of gravitational pull on standing bodies of water, how does the present-day lake elevation compare between that at Little Cone Campground and Paulina Outlet? Are the lake levels at equal elevation or different? Water sits flat on the earth's surface if its contained- the slope is zero. The water elevation at Little Cone and Paulina Outlet is exactly the same.

H. Compare and describe your observations for the shoreline topography between the west and east ends of Paulina lake (refer to map p 161 for geographic frame of reference). The shoreline at the west end of the lake is higher than the shoreline at the east end by some meters.

I. Now relate your answer in "H" above to Figure 6 shown on p 149 of your field guide. Given all of the data and observations, provide at least two hypotheses to explain lake and/or geologic processes that could result in the lake terrace relationships between the east and west ends of Paulina Lake. 1. The east end of the lake is uplifting due to continued volcanic activity at Paulina Lake, while the west end is not. After all, the Little Crater eruption was one of the last, if not the very last events to take place in the history of Newberry Crater. Magma could be pushing up in this area, lifting the land there. 2. The east end of the lake is not uplifting, but is just being eroded by wave action, while the west end is receiving deposition because it is at the outlet- a slow current moves in that direction, carrying silt and then depositing it there. Prevailing winds are toward the east end- the end that is being eroded. The prevailing wind would typically push waves in the direction eastern bench, and we see evidence of erosion where we expect it.

The answer is probably both of these hypotheses. I recall your explanation- that scientists had at least done some rough measurements, indicating the east end was indeed uplifting slowly. We discussed putting in some very expensive seismic detectors and GPS units that could measure mm's (or some very small unit) of upward movement, graph all that over time, and prove our hypothesis. We discussed how expensive that would be, and how unlikely it is, given the cost.

Paulin Lake is approximately circular in outline, with an average deameter of 2.8 km and an average depth of 50 m.

J. Calculate the area of Paulina Lake in acres and hectares. Show all math.

(J.) Dia = 2.8 Km, depth = 50 m avg.

Area = $\pi r^2 = (3.14)\left(\frac{2.8}{2}\right)^2 Km^2$

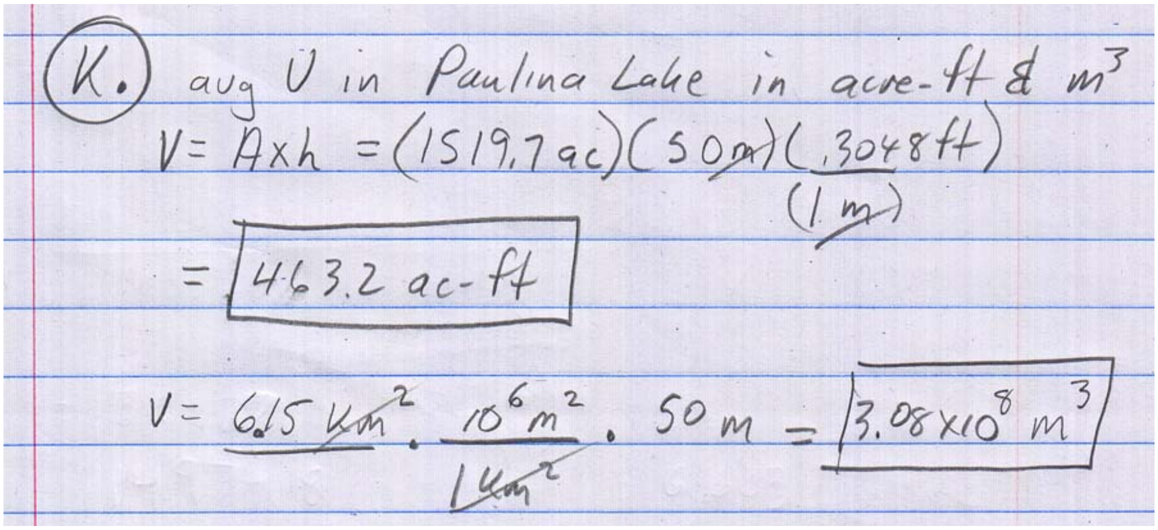
answer in Acres, Hectares

$(3.14)\left(\frac{2.8}{2}\right)^2 Km^2 = \boxed{6.15\ Km^2}$

$(6.15\ Km^2)\left(\frac{247.1\ ac}{Km^2}\right) = \boxed{1519.7\ \text{Acres}}$

$\boxed{6.15\ Km^2}\ \frac{100\ ha}{Km^2} = \boxed{615\ ha}$

K. Calculate the average volume of water contained in Paulina Lake in ac ft and m^3. Show all math.



(K.) avg V in Paulina Lake in acre-ft & m^3

$V = A \times h = (1519.7\ ac)(50\ m)\left(\frac{.3048\ ft}{1\ m}\right)$

$= 463.2$ ac-ft

$V = 6.15\ km^2 \cdot \frac{10^6\ m^2}{1\ km^2} \cdot 50\ m = 3.08 \times 10^8\ m^3$

L. Using your field guide, determine the elevation of Paulina Lake outlet at the west end of the lake, where the resort road crosses Paulina 'Creek. The benchmark shown on the map indicates 6331 ft above sea level.

M. What is the lake level elevation, as compared to the outlet elevation? It is exactly the same. The map shows 6331 feet.

N. Given that the average annual discharge of Paulina Creek is 18 ft3/sec, how long would it take to totally drain Paulina Lake if all inflows were eliminated? Answer in days and years, show all of your math.

(N.) How long to drain Paulina Lake?

$Q = 18\ ft^3/sec$ in days, years

$V = 3.08 \times 10^8\ m^3$

$$\frac{3.08 \times 10^8\ m^3}{1}\left(\frac{sec}{18\ ft^3}\right)\left(\frac{1\ ft^3}{.02832\ m^3}\right) = sec$$

$$= \frac{3.08 \times 10^8}{(18)(.02832)} = 6.04 \times 10^8\ sec$$

$$\left(\frac{6.04 \times 10^8\ sec}{1}\right)\left(\frac{1\ day}{86{,}400\ sec}\right) = 6.99 \times 10^3\ day$$

$= 6{,}990$ days $= 19.15$ years

Part 2- Paulina Falls Knickpoint Problem

Stream gradient is the measure of the amount of vertical drop per unit horizontal distance (i.e. "rise/run", as measured along a stream channel. Gradient is essentially a measure of the gravitational shear force oriented parallel to the longitudinal profile of the stream channel, i.e. the higher the gradient, the higher the shear force associated with flowing water. The power of the flowing water (energy expenditure per unit time) is directly proportional to the discharge (volume/time) and the gradient (ft/ft) of the river; the higher the discharge and gradient, the higher the stream power and energy available to do geomorphic work (erosion and transportation).

A. Figure 2 on p. 149 of the field guide is a longitudinal profile of Paulina Creek, extending from the outlet at Paulina Lake to the confluence with the Deschutes River. Calculate the average gradient of Paulina Creek between the Paulina Lake outlet and Ogden Group Camp. Answer in ft/mi and ft/ft. Show all of your math.

(A) - calculate gradient in ft/m & ft/ft

6331 ft' → 4200' Δ = 2131' = y

x = 13.5 m' = 71,280'

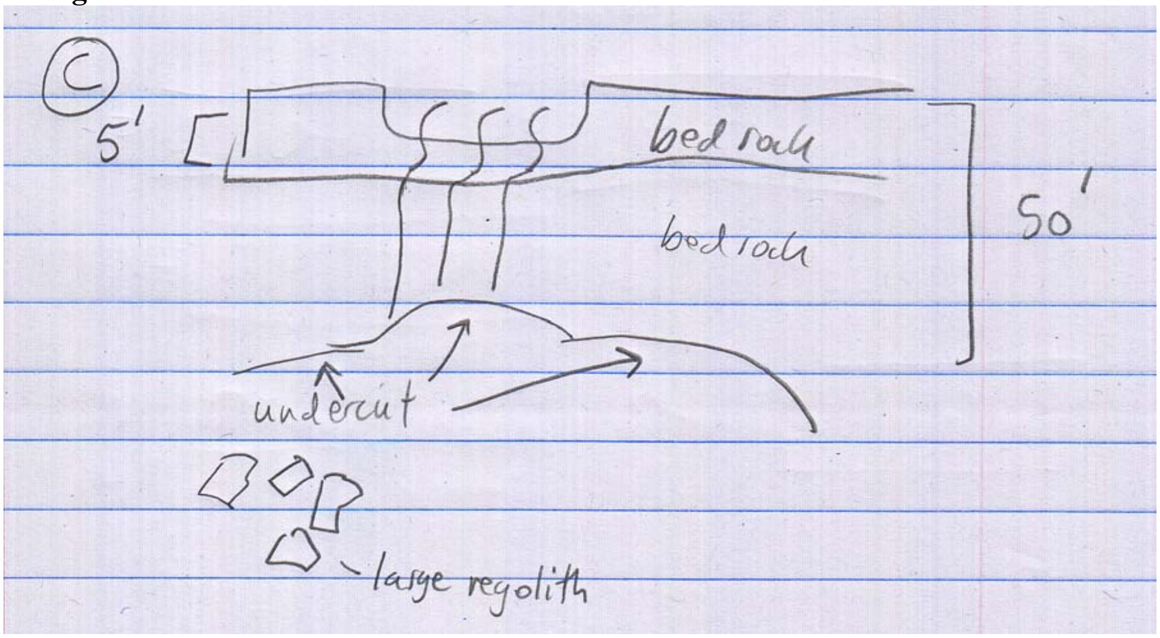
gradient = $\frac{\Delta y}{\Delta x} = \frac{2131'}{71,280'} =$ **0.03 ft/ft**

$\frac{\Delta y}{\Delta x} = \frac{2131'}{13.5 mi} =$ **$\frac{157'}{mile}$**

B. We will be visiting the overlook at Paulina Falls. Hopefully you are looking at Paulina Falls presently. Geomorphically, the technical term for a water fall is "knickpoint", hence you are looking at the "Paulina Knickpoint". Using the available field tools provided by your professor and the trigonometric functions illustrated on p 129 of the field guide, determine the height of Paulina Falls in meters. Draw a sketch of the trigonometric relations and show all of your math.

We can't do this since we didn't do any of these types of observations when we were there. However, I would estimate the height at about 50 feet, using the large dead snag diameter in the top left of the picture as a guestimate standard.

C. Using the longitudinal profile on p 149 of the field guide, and your own direct observations, draw a scaled field sketch of Paulina Falls. Include observations on the bedrock geology, channel configuration and relief.



D. As described in 2A above, calculate the gradient of Paulina Creek at Paulina Falls. Answer in ft/mi and ft/ft. Show all your math.

You can't do a gradient. Y = 50 ft. X = 0. 50/0 = infinity. In other words, there's one definition for a knickpoint- slope cannot be defined because it is straight up and down.

E. Based on your observations and gradient calculations along Paulina Creek, write your own definition of the term "knickpoint" as applied to stream channels. Once completed, compare your answer to the notes listed on p 24 of the field guide.
A knickpoint is when there is a vertical drop. The gradient is undefined, mathematically speaking. A knickpoint is where a stream is going to break down underlying material catastrophically at some point in the geologic future. I looked it up, I'm close but too specific. Knickpoints exist because of resistance of rock at that point and they are steep. True, if slope is undefined, you have a knickpoint, but you can just have a very steep slope and that will be a knickpoint as well.

F. Examine fig 6.42 on p 101 of the field guide and relate it to paulina Falls. Paulina Falls is undergoing parallel retreat as blocks of bedrock chip off vertically. **Are knickpoints erosional or depositional landforms?** They are both- if you erode, you have to deposit it somewhere. Just downstream from the falls are very large rocks caused by parallel retreat. **List and briefly discuss three hypotheses as to what geologic processes or features could result in knickpoint development along a river channel. 1**. Resistant surface. 2. Deposition of landslide. 3. Man made. **What will happen to the Paulina Falls knickpoint over time- is it mobile or stationary?** The knickpoint will undergo headward progression- it will move upstream over time. **How will it evolve in terms of form and position over time?** I didn't look, but as long as it is carving into bedrock, and as long as the general characteristics don't change, then headward erosion will continue and it will be of the same character- parallel retreat.

G. If you were a steelhead, salmon, or trout living in the Deschutes River basin, what would be the significance of channel knickpoints in terms of your aquatic ecosystem? Knickpoints have the potential of blocking migration of fish, bad news for steelhead, salmon and trout. Of course, local trout would be ok, but not migratory fish if they want to inhabit above a knickpoint. If they can't jump it, they can't inhabit upstream. Thus, artificial knickpoints like dams push fish downstream and keep them there. **How do knickpoints affect your life and the place where you live in the basin?** If you mean I am a fish, then the knickpoints determine how far upstream I can live. If they are dams, that means I have to catch a barge. It also means the artificial knickpoint changed where we can live.

Part 3 - Incision Rate Problem

Two 10 m thick deposits of rounded gravels are located at points A and B on figure 3A, p 235 of the field guide (profile showing Deschutes Geology and Topography vs. elevation). Basaltic lava flows capping the respective gravel layers were isotopically dated at 4 m.y.old (Pliocene). Assuming that the gravels are deposits of the Deschutes River, answer the following questions:

A. What is the likely depositional origin of the rounded gravel layers? These are gravels, so they are not easily suspended in slow water- they must have been deposited during a flood.

B. What is the youngest age that can be applied to the gravel deposit, meaning how long ago was it deposited? What is your line of evidence? The Basaltic flow capping the gravel is about 4 m.y. old. The gravel must be older than that. (I believe you are referring to the age when the gravel was deposited, not the age of the parent material of the gravel). I re-read the literature. The basaltic flow is too young to be CRB, and although we never discussed the Dalles formation, that's what the 4 million year old basalt flow is. So, the best we can say is that the gravel was deposited just before 4 million years ago, when the Dalles Formation was laid down.

C. What is the name used to define the flat surface upon which the rounded gravels are deposited. A river terrace. This was the river bed, then as the river incised, and the river shifted to one side or the other, it got left behind, as a terrace.

D. Using figure 3A on p 235, calculate the minimum incision rate at which the Deschutes River has been down-cutting it's canyon since 4 m.y. ago. Answer in mm/t.y and cm/t.y (t.y.= thousand years). As a method, and a check, I calculated the change in elevation at point A and at point B. Given the limits of accuracy in using this chart, they are pretty much the same- 300 m of incision over 4 million years. Also, connecting point A and B, I drew a slope for the ancient Deschutes. It matched the current river slope. Incision at both A and B then, was very much the same. So I calculated only one of them. 300 m = 300,000mm. 4,000,000 yrs = 4,000 thousands. 300,000/4,000 = **75 mm/t.y**. 75 mm/10mm = **7.5 cm/t.y**.

E. Compare your answer to published, long term average incision rates shown on Table 1, p 99 of the field guide.

-What are the highest average incision rates listed on p 99 (cm/t.y)? The largest is 157,000 cm/k.y. (a knickpoint migration was involved- I think you sort of have to set that one aside, in its own category). Next is 1000 cm/k.y.

-Where are the highest rates located? The knickpoint incision was in Ontario, humid temperate climate, with the largest drainage area on the chart, passive tectonics. The two drainages with 1000 cm/k.y were in Japan and Pakistan. The Japanese river was in a humid temperate climate with a very small drainage, uplifting tectonics and the Pakistani river is in a semiarid climate, with a large drainage basin, uplifting tectonics.

-What type of bedrock (lithology) are the highest rates associated with? The Canadian incision (largest) is associated with sedimentary rock. The Japanese incision is associated with mudstone (it even sounds soft), and the Pakistani incision is associated with igneous and metamorphic rock.

-What are the lowest average incision rates listed on p. 99 (cm/t.y.)? 0.5-3, basaltic/metamorphic, Australia; 2.7 in Carbonates and crystalline rock, Virginia; 0.5-8 basalt, Kauai.

-Do all rocks and rivers erode at the same rate? Explain your answer. Obviously not. It appears to be dependent on many factors, though harder rocks are harder to incise, and softer rocks are easier to incise. Looking over the chart, drainage size helps, though this is in turn mitigated in some arid environments. A big drainage doesn't always mean a lot of flood events. As I said, its complex.

-What is the total drainage area of the Deschutes River Basin (sq. km)? 26,860 sq. km.

-What is the long-term average incision rate that you calculated in 1D from above (in cm/t.y.)? 7.5 cm/k.y.

-In comparing Deschutes drainage area and average incision rate to those listed on p 99, which locations are most similar? What is the age of the rocks at those similar locations listed on p 99? What is the rock type at those similar locations listed on p 99? The Colorado and Sierra Nevada incision rates are most similar. Both are Pliocene-Quaternary. (5.3 m.y. old). The incision in Kauai, is also similar if you use its upper range (0.5-8). It is also Pliocene-Quaternary. The Sirerra incision is granite/andesite- hard rock. The Colorado incision is metamorphic and the Kauai incision is basalt. I have to assume the Colorado metamorphic rock is a very hard metamorphic.

-Comment and discuss whether the Deschutes River is associated with average, below or above average incision rates compared to other published studies. A rough average of the data on p 99, excluding the large knickpoint incision in Ontario, is 128 cm/k.y. The Deschutes is well below the average, at 7.5 cm./k.y. I imagine this is in part because of the CRB's which capped the whole region, and the other basaltic flows that occurred throughout the history of the river.

- List and discuss the variables that control the incision rate of any given drainage basin. Drainage size, lithology, climate, tectonic factors, and I'm guessing, to some extent, the amount of time. The last is probably important because incision rates surely vary. For example, I would bet that the incision rate through the CRB's was much slower than the incision rate through the John Day formation. So, if a river has varied stratigraphy, and has been incising over a long period of time, its going to have a different incision rate, possibly, than it would if you measured it at some other time, either much earlier, or much later. (I'm speaking in geologic time reference). It seems to me that incision rates can be considered in a general way, yet looking over the table, you really have to say that its highly specific to individual circumstances. The best I can say from looking at the table is that hard rock takes longer to incise.

Part 4- Deschutes Basin Water Budget Analysis

Refer to the location map of the Deschutes River basin on p 232 of the field guide. The total drainage area of the basin is 27,200 km^2. The Deschutes is climatically and physiographically divided into two distinct sub-regions, the wetter western portion comprised of the High Cascades (covering about 10% of the total basin area), and the drier eastern portion comprised of the Ochoco Mountains, Newberry Volcano, and High Lava Plains (covering about 90% of the total basin area). The western (Cascades) portion receives an annual average precipitation of 1500 mm/yr, while the eastern area receives approximately 250 mm/yr. In addition, the average annual discharge of the Deschutes River at its outlet near the Columbia River gorge is on the order of 175 m^3/sec. Your task is to conduct a cursory hydrologic analysis of the Deschutes watershed, based on the following questions:

A. Calculate the hydrologic parameters listed in the table below (show all work).

Sub area of western portion (km^2) ______________ **m^2**__________________

(W) 27200 km^2 (.90) = [24480 × 10^6 m^2] West

Sub-area of eastern portion (km^2) ______________ **m^2**__________________

(A-) (E) 27,200 Km^2 × (.10) = [27 20 × 10^6 m^2] East

Average annual precipitation western (in/yr) ______________

(W) $\frac{(1500 mm)(1 cm)}{10 mm} \times \frac{1 in}{2.54 cm}$ = [59.05 in/yr.] west Av precip

Average annual precipitation eastern (in/yr) ______________

(E) $\frac{(250 mm)(1 cm)}{10 mm} \times \frac{1 in}{2.54 cm}$ = [9.8 in/yr] east av precip

Average annual precipitation western (m/yr) ______________

(W) $\frac{1500 mm}{yr.} \cdot \frac{m}{1000 mm}$ = [1.5 m/yr.] Av prec. W

Average annual precipitation eastern (m/yr) ______________

(E) $\frac{250 mm}{yr} \cdot \frac{m}{1000 mm}$ = [0.25 m/yr] Av prec E

Total Precipitation Input Volume for year Eastern (m^3) ____________________

(E) $\left(\frac{0.25\ m}{yr}\right)\left(2720 \times 10^6\ m^2\right) = 680 \times 10^6\ m^3$

Total rain/yr, East

$= 6.8 \times 10^8\ m^3$

Total Precipitation Input Volume for year Western (m^3) ____________________

(W) $\left(\frac{1.5\ m}{yr}\right)\left(24480 \times 10^6\ m^2\right) = 36720 \times 10^6\ m^3$

$= 3.7 \times 10^{10}\ m^3$

Total Rain/yr West

Total River Discharge Output volume for Year at Outlet (m^3) ____________________

Total Disch Q_{annual}

$\left(\frac{175\ m^3}{sec}\right)\frac{60\ sec}{min}\ \frac{60\ min}{hr}\ \frac{24\ hr}{day}\ \frac{365\ days}{yr}$

$= 5.52 \times 10^9\ m^3/yr$

Total Annual Precipitation Input- Total Discharge Output (m^3) ______________________

Annual Precip − Q_{annual} = m^3

East ($6.8 \times 10^8 m^3$)

+West ($3.7 \times 10^{10} m^3$)

37000000000
680000000

3768×10^7 = $3.77 \times 10^{10} m^3$ Total Annual Precip

[$3.77 \times 10^{10} m^3/y$ rain] − [$5.5 \times 10^9 m^3/y$ output]

= 37700000000
5.5

322×10^8 = $3.22 \times 10^{10} m^3$ LOST

Total Annual Percent Loss of Precipitation During Drainage Process (m^3) ______________________

$\% = \frac{3.22 \times 10^{10} \text{ LOST}}{3.77 \times 10^{10} \text{ Total}} = .85 = 85\%$

B. Compare the total annual precipitation input volume to the discharge output volume for the Deschutes basin. Provide a hypothesis and explanation to account for the differences.
When you compare the numbers, as seen directly above, you can see that 85% of the precipitation that falls onto the basin is "lost"- it doesn't show up at the output gage. The Deschutes area is dry, and although there is plenty of rock, there is enough sandy, permeable soil to absorb most of the rain. No only that- the rock itself is cracked throughout- allowing deep percolation of deposited rainwater.

C. Examine the stream hydrographs on Figure 6, p 240 of the field guide. Compare the annual stream hydrograph of the North Fork of the Crooked River (east side drainage in Ochoco Mtns) to that of the Metolius river (west side drainage in Cascades).

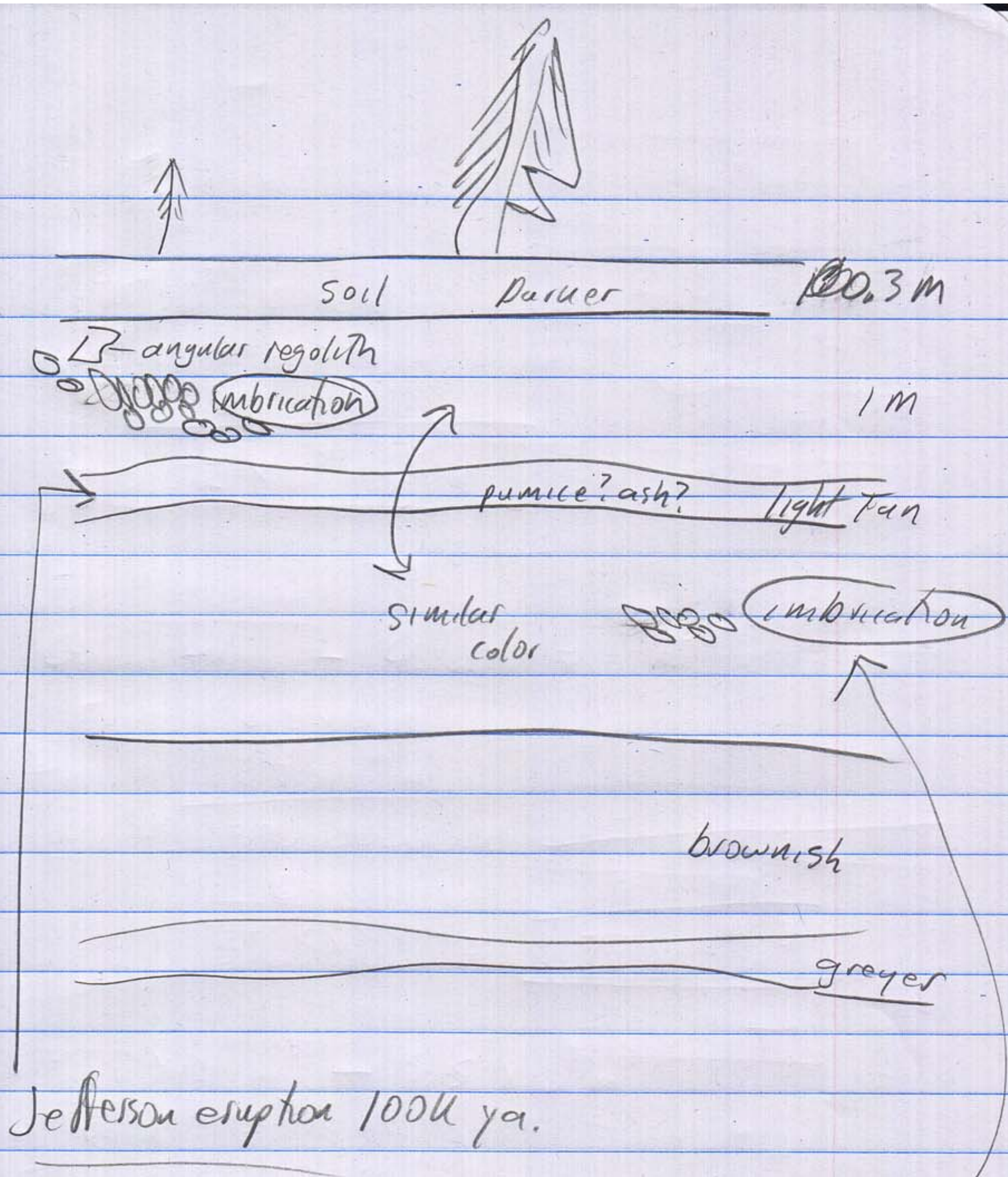
Critical questions: Are there significant seasonal discharge variations? Yes there are significant variations on the North Fork of the Crooked River. On the Metolius, the fluctuations are very very small- it's flow is basically unvarying. **If so, when are the "wet months", when are the dry months? Compare each river.** The Metolius has no "wet" vs "dry" cycle, at least with respect to its actual flow. The North Fork of the Crooked river has a high flow from around mid-January to Mid July.

Now compare the Metolius and N. Fork Crooked River hydrographs to those of the main stem of the Deschutes near Madras and at Moody. Are the main-stem Deschutes hydrographs more seasonally similar to the west-side Metolius record or the east-side Crooked River record? Is the overall Deschutes more "west side" or "east side" in character? The North Fork of the Crooked River shows east side characteristics- it fluctuates with precipitation and snow melt cycles. The Metolius shows no real fluctuation. The Main Deschutes gage, near its confluence with the Columbia, shows the Deschutes doesn't fluctuate much, but certainly a bit more than the Metolius. The main Deschutes is certainly more west side in character.

D. Examine Figure 3 on p 233 of the field guide, generalized geologic map of the Deschutes basin. Compare and contrast the bedrock geology from the west-Cascade side of the basin, to the east-Ochoco side. What are the primary rock types? How old are they?
The rocks on the west side are quaternary volcanics of the Cascades, meaning they were put there in the last 2 million years. On the east side are Miocene (2-25 Ma) basalt flows (CRBs mostly), Oligocene (25-35 Ma) John Day and Eocene (35+Ma) Clarno.

E. Based on your above analysis, provide hypotheses to explain the seasonal hydrograph variations between the west and east sides, and how they compare to the main stem of the Deschutes. What geologic and climatic factors could explain the seasonal differences and/or similarities (hint: figures of p 241 will get you heading in the right direction). Younger, volcanic (i.e. ignimbritic) cascades deposits are very permeable, while CRBs, John Day and Clarno, are not. CRBs by their intitial nature are not permeable. John Day and Clarno are probably less permeable because they have become consolidated, however poorly, over time. So, the Deschutes and Metolius rivers, where they are adjacent to and receive groundwater from the Cascades, are steady flowing rivers. Because the Deschutes also receives water from east side tributaries, it has more fluctuation then the steadiest river of them all, the Metolius. East side rivers fluctuate a lot- they really don't get any groundwater. To round out the picture, the west side, as we have seen in our excercises, receives a tremendous amount of snow which melts and permeates into the granular soils there, while the east side is in the rain shadow. When it does get rain, it is not retained as groundwater.

L. Trout Creek Road Cut- stratigraphic Cross-Section and Interpretation **

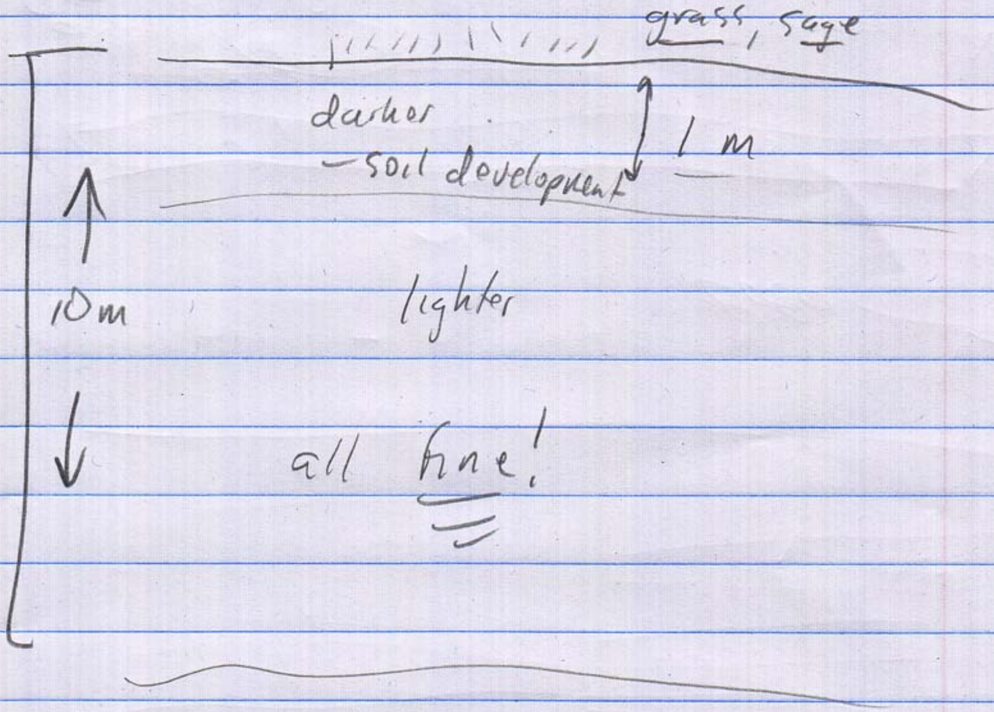


This is a series of terraces or perhaps actual river bed - as indicated by the imbricated, rounded gravels. The upper layer is soil - last 10's of Thousands of years. The layer from the ash to surface is 100,000 years old to Present, using Jefferson Layer!

M.Highwyay 197 Roadcuts Near The Dalles Cross Section / Stratigraphic Interpretation [***]

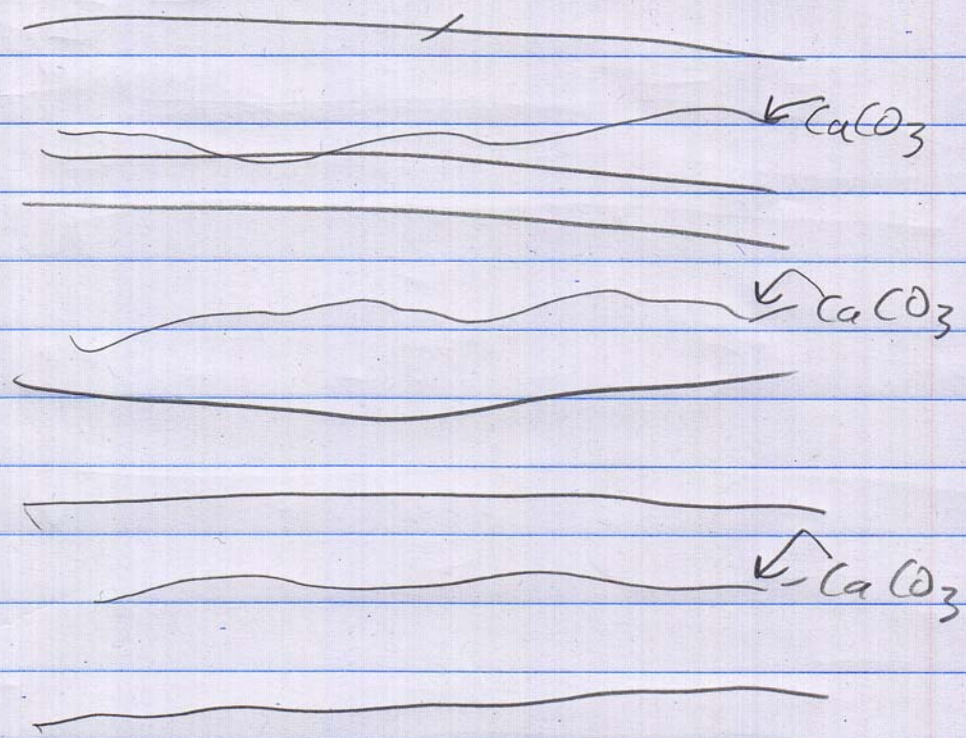
Road Cut 197

Loess or Missoula Deposit



This is loess or ~~the~~ transported Loess from Missoula Flood. Could be loess blown by catabatic winds from Cordilleran Sheet / Okonagan lobe.
~~Sandwiched~~ (Left to right) between Dalles formation bedrock.

Other cuts - 197 - generally



17-7 Ma - about same age as CRB'S.
Dalles formation - uphill of the Loess Deposits. Mostly Light colors. Ignimbrite - tuffaceous, ashy deposits - probably from ancestral cascades. Repeated layers of aridisols indicate paleosols - soil had time to develop between flows. Mt Hood only 35 mi away!

Acknowledgments ***

Many thanks to: Ed Bartlett and friends at Blue Fish Rafting for supplying excellent gear, great attitudes and lots of smiles; Western Oregon University for vehicles and the opportunity to take a different kind of course; Dr. Stephen Taylor for daring to do it; All of the former students who contributed numerous photographs and Dr. Taylor for taking the time to post them all on his website; My colleagues who attended this course: Thomas, Katie, Jodi, Todd, Nathan, Joe, Kevin, Jill, Britney, and Kristine for fun, intellectual stimulation and good dining companionship.

References / Preparatory Readings ***

Orr and Orr 1999 Overview of Oregon Geology
Orr and Orr 1999 Overview of the High Lava Plains
Jenson and Chitwood, 2000- Overview of Newberry Volcano
Orr and Orr 1999 Overview of the Deschutes-Columbia Plateau
O'Conner et. al., 1995 Overview of the Missoula Floods
Orr and Orr, 1999 Overview of the Willamette Valley

Appendix- Copies of Field Notes ***

GS407/507 River Environments – Stream Ordering Exercise

Introduction

Watersheds represent a collection of stream tributary networks with interconnected branches that flow from drainage divides (interfluves) to the exit point, downstream. Smaller-area watersheds are in turn connected to larger-area watersheds until they reach a scale that empties into the ocean. The primary physical function of the stream network is to deliver water and sediments over time, under the influence of gravity. The sediment or water discharge of a river system is calculated by:

Q = vol. / t where Q = discharge, volume = vol. of sediment or water, and t = time.

Gravitational force is the driving mechanism moving sediment and water downstream, climate-derived rainfall/precipitation is necessary for water flux, the sediment and water transported by the river represents its "load", and the discharge represents the "output" of the watershed over time. The number and types of tributary connections in watersheds are important factors that control the output. The critical controlling morphometric parameters include:

Drainage basin area (i.e. precipitation "catchment" area)
stream gradient (slope of channel = gravitational force)
Number of stream segments in the network
Lengths of stream segments in the nework

An example of these controlling factors is:

The greater the drainage basin area and the steeper the stream gradient, the greater the volume of water and faster the stream velocity, the greater the energy to transport sediment = higher discharges of water and sediment over time.

The following exercise illustrates the analytical techniques used to characterize the physical drainage morphometry of a watershed.

Exercises

Examine the map of the watershed and drainage network shown on the following page.

1. ✓ Label the drainage boundary on this map. Label the tributary outlet for the watershed.
2. ✓ Compare the map to the drainage patterns shown on "Figure 5.2A" on p. 32 of your field guide. What drainage type is associated with this map? Zone 1, production basin.
3. ✓ Using the drainage pattern as a guide, draw drainage divides around the stream network systems labeled "sub-basin 1", "sub-basin 2", "sub-basin 3", "sub-basin 4", "sub-basin 5", and "sub-basin 6".
4. ✓ Using the "Strahler stream ordering method" illustrated on "Figure 5.17", p. 34 of your field guide, determine and label the stream order numbers for each tributary in the watershed. Label the stream order numbers next to the stream segments on your map.
5. Answer the following questions:

What is the highest stream order of the basin? 5
How many total first order stream segments are there? = 287
How many total second order stream segments are there? = 73
How many total third order stream segments are there? = 17
How many total fourth order stream segments are there? = 5
fifth → 1

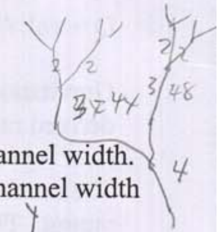
What is the general relationship between stream order and the no. of stream segments in the order? Plot the general relationship on an x-y graph, with stream order on the x-axis, and number of segments on the y-axis.

See attached graph

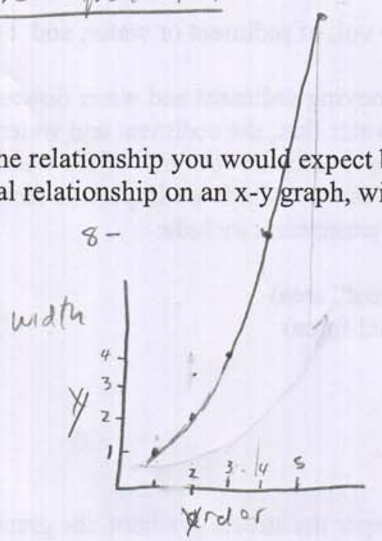
summary:

1 – 287 1X
2 – 73 2X
3 – 17 4X
4 – 5 8X
5 – 1 16X

–reverse exponential.



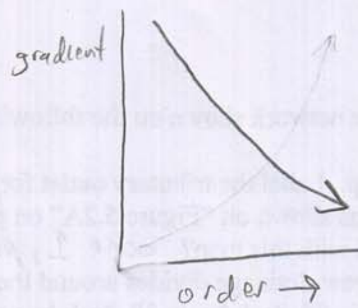
Hypothesize the relationship you would expect between stream order and stream channel width. Plot the general relationship on an x-y graph, with stream order on the x-axis, and channel width on the y-axis.



Y=

X	Y
1	1
2	2
3	4
4	8
5	16

Hypothesize the relationship you would expect between stream order and channel gradient. Plot the general relationship on an x-y graph, with stream order on the x-axis, and channel gradient on the y-axis.



More stream order, lower gradient.

If the bedrock underlying a given watershed was very porous and permeable (i.e. sponge-like), would you expect the number of stream channel segments to increase, decrease, or stay the same? Why, explain your answer.

Decrease, if every thing else held the same. Why – some 1's wouldn't exist – H_2O would become groundwater. However, the ultimate deposit would have a steadier flow (i.e. Deschutes)

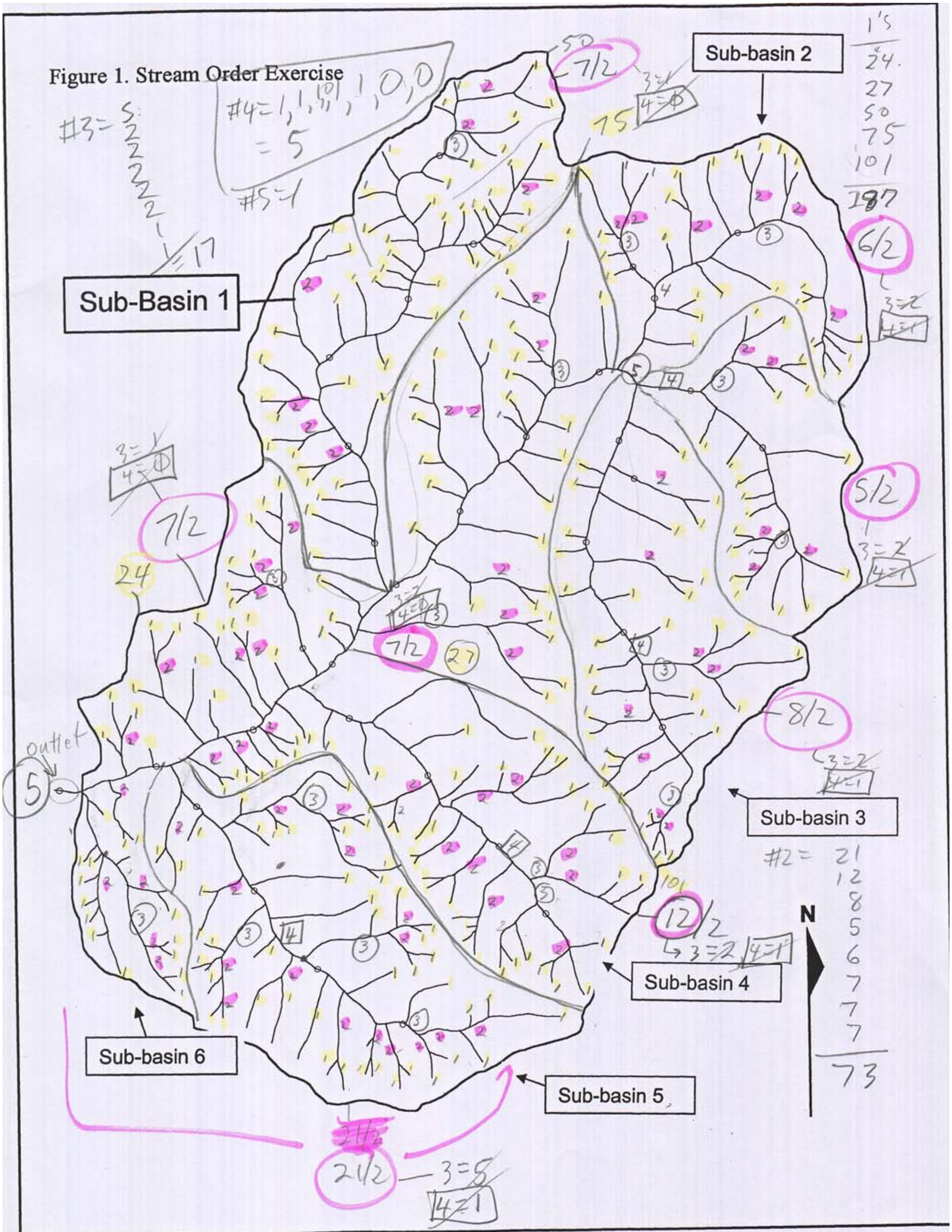


Figure 1. Stream Order Exercise

GS407/507 River Environments – Fluvial Hydrology Problem Set

Using the equation lists on p. 35-47 of your field guide, and the unit conversion charts on p. 123-130, solve the following problems. Show all of your math work and calculations!

1. The rational runoff method predicts peak runoff rates (discharge = vol / time) from data on rainfall intensity (i.e. rainall into drainage basin) and watershed characteristics (e.g. underlying bedrock type and infiltration capacity). The governing equation is:

$$Q_{pk} = 0.278CIA$$

Where Q_{pk} = peak discharge of drainage basin in m^3/sec, I = rainfall intensity in mm/hr, C = infiltration factor of watershed (asphalt/concrete = 0.80, thin soil over bedrock = 0.40), and A = drainage basin area in km^2.

A. Determine the peak discharge (in cubic meters per second) for a drainage basin experiencing a rainfall event with the following characteristics: drainage area = 10,000 acres, rainfall intensity = 1.25 cm/hr, and substrate = loamy soil over sandstone. Show all of your work.

B. If a drainage basin has an area of 175 km^2 and experiences a 30 mm/hr rainfall event with a 500 m^3/sec peak discharge, calculate the infiltration factor for the watershed. Show all of your work. Based on your answer, is this watershed likely rural/forest or highly urbanized? Explain your reasoning.

C. If 30% of a forested, 1000 km^2 watershed is urbanized, calculate the anticipated peak runoff associated with a 0.5 in/hr rainfall event.

2. If a river channel has a discharge of 5 ft^3/sec and a cross-sectional area of 5 m^2, calculate the average velocity of the river in m/sec. Show all of your math work.

3. Empirical data show that hypothetical watersheds in the western Cascades have peak flood discharges every 2-3 years as described by the following equation:

$$Q_{2.33} = 34.5A^{0.93}$$

Where Q = peak discharge in ft^3/sec and A = drainage area of a given basin in acres. Calculate the expected peak discharge for a drainage basin with an area of 125 km^2. Show all of your work.

(A.) $A = (10{,}000 \text{ acres}) \dfrac{4047 \text{ m}^2}{1 \text{ Acre}}$

$I = \dfrac{1.25 \text{ cm}}{\text{hr}} \times \dfrac{1}{1 \text{ cm}}$

$C = .40$ (loamy soil)

$Q_{pk} = (.278)(.40)\dfrac{(1.25 \text{ cm})}{\text{hr.}}\dfrac{(\text{m})}{(100 \text{ cm})}\dfrac{10{,}000 \text{ acre}}{1 \text{ acre}} \cdot (4047 \text{ m}^2) \cdot \dfrac{1 \text{ hr}}{3600 \text{ sec}}$

$= \dfrac{5{,}625{,}330 \text{ m}^3}{360{,}000 \text{ sec}} = \boxed{\dfrac{15.6 \text{ m}^3}{\text{sec}} = Q_{pk}}$

$Q_{pk} = \dfrac{500 \text{ m}^3}{\text{sec}} =$ $\quad I = \dfrac{30 \text{ mm}}{\text{hr.}}$ $\quad A = 175 \text{ km}^2$

$Q_{pk} = .278\, C I A$

$\dfrac{Q_{pk}}{.278 I A} = C \quad \dfrac{500}{(.278)(30)(175)} = \dfrac{500}{1459.5}$

(B) $Q_{pk} = .278 C I A$ ↳ No units, I - mm/hr → 30

A - $\text{km}^2 = 175$

$Q_{pk} = .278 C I A$

$\dfrac{Q_{pk}}{.278 I A} = C = \dfrac{500 \text{ m}^3}{\text{sec}} \cdot \dfrac{1}{(278)(175)(30)}$

$C = .34$ (Taylor left out the conversion units for C)

If $C = .34 \cong$ likely rural forest.

(C) $Q_{pk} = Q_F + Q_u \qquad I = \frac{0.5\,in}{hr.}$

$$Q_{pk} = \underbrace{[.278(I)] \cdot C_F A_F}_{Q_F} + \underbrace{[.278(I)] \cdot C_u A_u}_{Q_u}$$

$$\left[(.278)\left(\frac{0.5\,in}{hr}\right)\left(\frac{2.54\,cm}{1\,in}\right)\left(\frac{m}{100\,cm}\right)\left(\frac{1\,hr}{3600\,sec}\right) \right]$$

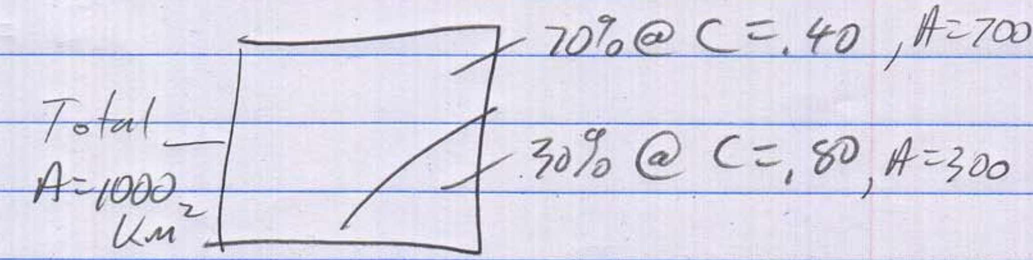
$$\boxed{9.81\times10^{-7}\ \frac{m}{sec}}$$

$$\left(\frac{9.81\times10^{-7}\,m}{sec}\right)(.40)\left(\frac{700\,km^2}{1}\right)\left(\frac{10^6\,m^2}{1\,km^2}\right) = \boxed{274.68}$$

$+$

$$\left(\frac{9.81\times10^{-7}\,m}{sec}\right)(.80)\left(\frac{300\,km^2}{1}\right)\left(\frac{10^6\,m^2}{km^2}\right) = \boxed{\frac{235.37\,m^3}{sec}\ \text{urban}}$$

$$\boxed{Q_{pk} = 510.05\ \frac{m^3}{sec}}$$



(2) $Q_{pu} = \frac{5\,ft^3}{sec}$ and [box] x-sect = 5 m²

~~calculate~~

calculate velocity

$Q_{pu} = V \cdot A$, $A = 5\,m^2$, $V = ?$

$\frac{Q_{pu}}{A} = V$ $\quad \left[\frac{5\,ft^3}{sec}\right] \cdot \left[\frac{1}{5\,m^2}\right] \cdot \left(\frac{0.02832\,m^3}{1\,ft^3}\right) = V$

$Q_{pu} = \frac{(5)(0.02832)\,m}{sec} = \boxed{\frac{.1416\,m}{sec}}$ ANSW

(3) $Q_{2.33} = 34.5\,A^{0.93}$

Generally: $Q_x = a\,A^b$ $\quad$ x = interval, a = coefficient, b = exponent

$A = 125\,km^2$, $Q_{2.33}$ is in ft³/sec $\quad$ A = acres

$\left(\frac{125\,km^2}{1} \cdot \frac{10^6\,m^2}{1\,km^2} \cdot \frac{(3.28)^2\,ft^2}{1\,m^2}\right)^{0.93} \cdot \left(\frac{34.5}{1}\right)$

↖ A ↗ $\quad$ No - get into acres

$\left[(125)(10^6)(3.28)^2\left(\frac{1\,acre}{43560\,ft^2}\right)\right]^{0.93} (34.5) = Q_{pu}$

↓ 10.76

$\left(\frac{125\;10^6\;10.76}{43560}\right)^{0.93} (34.5) =$

$= (30877)^{0.93}\,(34.5)$

$(14974.8)(34.5) = 516{,}603\ ft^3/sec$

RI = Total yrs of record / # of disch > given value

Disch. = y
Recurrence = x

GS407 / 507 River Environments
Day 5 - Lab Exercise 4 at Buckskin Mary Campground – Middle Deschutes

Read over the notes on flood periodicity (i.e. "recurrence interval") as presented on p. 14, p. 39-40, p. 45, and p. 66 of the field guide.

1. A total of 60 years of river discharge data were collected for a hypothetical river. The peak discharges for each year were identified and tabulated (herein referred to as "Qp"). The data were ranked from 1 = highest Qp to 60 = lowest Qp for the 60 year period. As subset of the data below were selected from the 60-year record.

$RI = \frac{n+1}{m}$ n = total # events or yrs.   m = Rank of event, 1 = largest

Qp (cu. m /sec)	Rank	RI	Prob. = 1/RI
1300	16	61/16 = 3.81	.26 = 26%
500	53	61/53 1.15	.87
1100	23	61/23 2.65	.38
1700	6	10.16	.098
2200	2	30.5	.033
2000	3	20.3	.049
100	60	1.02	.98
300	57	1.07	.93
800	39	1.56	.64
1500	10	6.1	.16

Qp = Max disch (L^3/t)
Qp daily - max daily
Qp annual

A. Calculate the Recurrence Interval (RI) for each of the above discharges, answer in the space provided above.

B. Calculate the probability of occurrence for each of the above datum (p = 1/RI), answer in the space provided above.

C. Plot the recurrence interval –Qp data on the "Gumbel" probability graph on p. 69 of the field guide. RI is on the "x-axis", put Qp on the "y-axis". Use a y-axis scale of 10 tics = 500 cu. meters /sec.

D. Draw a best-fit line through the data, project the line to estimate Qp-100 (i.e. the anticipated discharge necessary for a 100-year flood.

E. Examine the graph you have created. Comment on the relationship between the frequency of small-scale floods vs. large scale floods. Which ones happen more often? How does the frequency of occurrence relate to the probability that a flood of a given magnitude will occur in a given year? $\frac{1}{RI} = P$ small floods happen more often

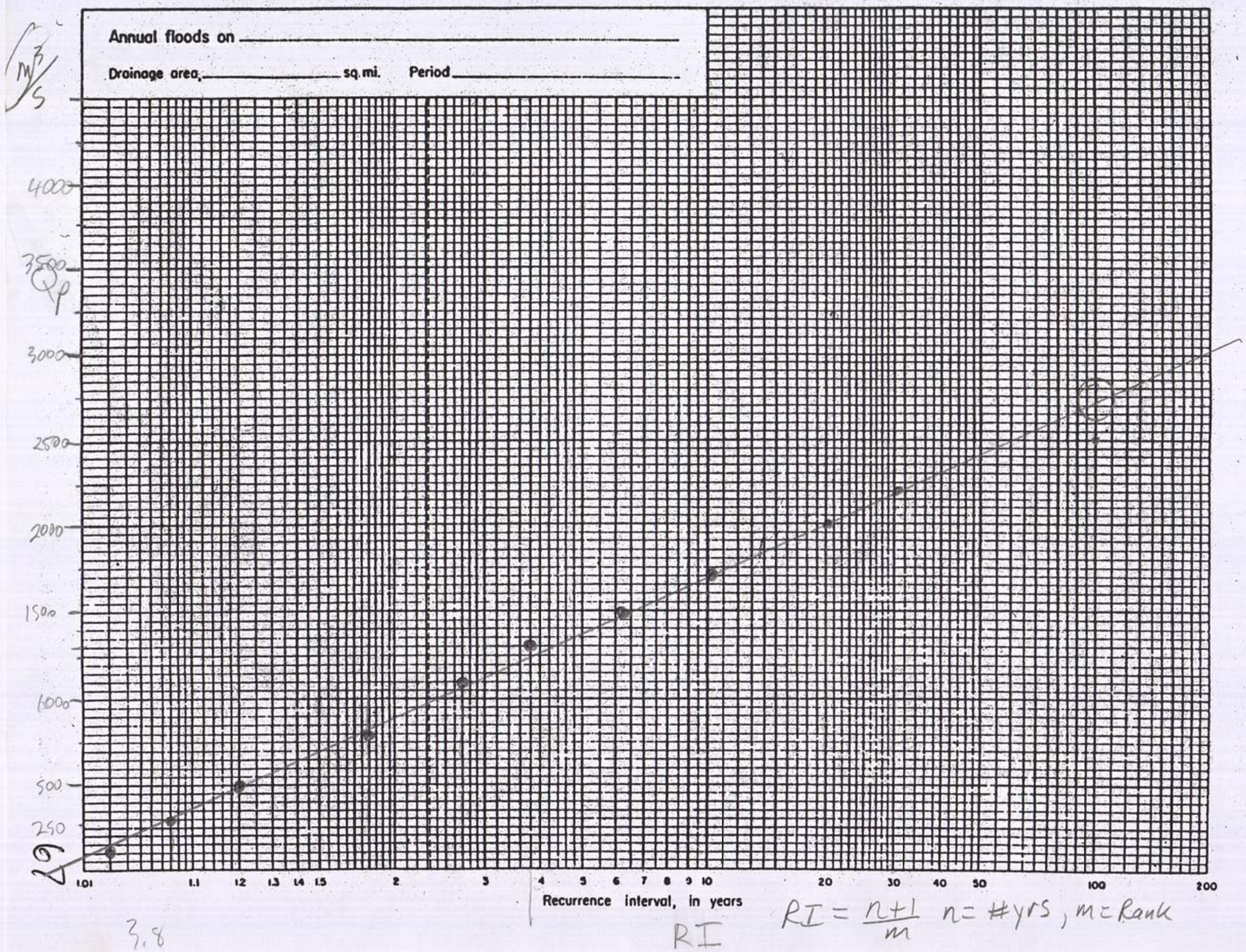
2. Examine the hillslope adjacent to Buckskin Mary Campground on river right. Compare the hillslope deposits and shape to the mass wasting diagram on p. 113 of the field guide. Identify the dominant processes responsible for the colluvial deposits that you observe.

Rock fall

3. Hike to the Dant overlook along the gravel road. Identify the landform and material that comprise the surfical deposit at the mouth of the steep canyon across the river. Draw a line around the boundary of this landform on the topo sheet on p. 173 of your field guide. What is the dominant process that resulted in this deposit? What observational evidence support you interpretation as to the process?

(MORE ON p. 212)

GUMBEL PLOT.



$RI = \frac{n+1}{m}$ n= #yrs, m=Rank

3.8 1300
1.15 500
2.65 1100
10.16 1700
30.5 2200
20.3 2000
1.02 100
1.07 300
1.56 800
6.1 1500

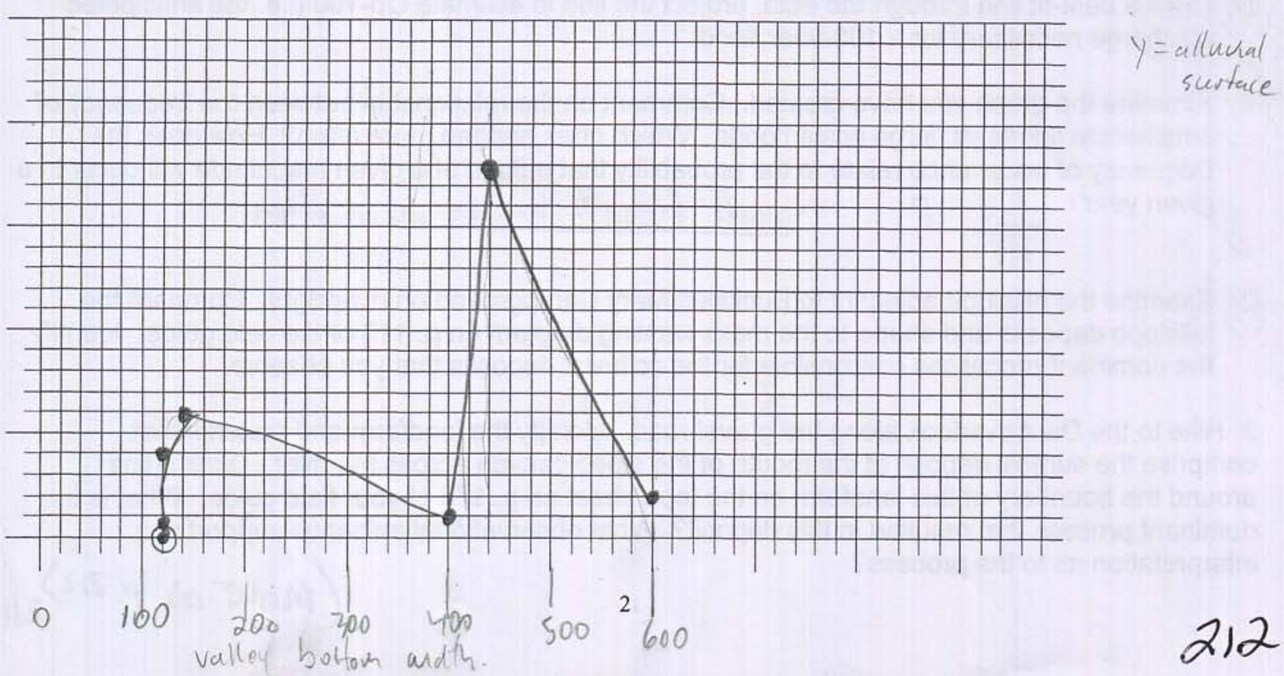
2700 100yr.
3000. 200yr.

4. Using the data presented on p. 235, plot an X-Y graph of alluvial surface area (y-axis) vs. valley-bottom width (x-axis). To derive the data, read the graphs on p. 235 and fill in the table below for the river-mile positions listed. After you fill out the table, plot the graph in the space below. Answer the summary questions.

River Mile	Valley-Bottom Width (meters) X	Alluvial Surface Area (hectares) Y
100	120	0
90	120	0
84	600	40
81	120	@ 12
79	400	2
73	440	36
67	~~360~~ 120	1
50	120	8

A. From your graph, describe the relationship on the Deschutes between volume of alluvial deposits in storage and valley-bottom width. What valley bottom localities would you most likely find a flood record that would preserve paleoflood stage indicators? Frame your answers in the context of valley width, transport energy, stream power and sediment-transport efficiency.

The Data & Graphs p. 235 are extremely hard to interpret, simply due to small size. You should find a relationship of: wide canyon = increased alluvial deposition. Why? - slow moving water in wide areas! Load settles out.



212

(J.) Dia = 2.8 Km , depth = 50 m avg.

Area = $\pi r^2 = (3.14)\left(\frac{2.8}{2}\right)^2 Km^2$

answer in Acres, Hectares

$(3.14)\left(\frac{2.8}{2}\right)^2 Km^2 =$ **6.15 Km²**

$(6.15\ Km^2)\left(\frac{247.1\ ac}{Km^2}\right) =$ **1519.7 Acres**

$6.15\ Km^2 \cdot \frac{100\ ha}{Km^2} =$ **615 ha**

(K.) avg V in Paulina Lake in acre-ft & m^3

$V = A \times h = (1519.7\ ac)(50\ m)\left(\frac{.3048\ ft}{1\ m}\right)$

= **463.2 ac-ft**

$V = 6.15\ Km^2 \cdot \frac{10^6\ m^2}{1\ Km^2} \cdot 50\ m =$ **$3.08 \times 10^8\ m^3$**

(N.) How long to drain Paulina Lake?

$Q = 18\ ft^3/sec$ in days, years

$V = 3.08 \times 10^8\ m^3$

$$\frac{3.08 \times 10^8\ m^3}{1} \cdot \left(\frac{sec}{18\ ft^3}\right)\left(\frac{1\ ft^3}{.02832\ m^3}\right) = \boxed{sec}$$

$$= \frac{3.08 \times 10^8}{(18)(.02832)} = \boxed{6.04 \times 10^8\ sec}$$

$$\left(\frac{6.04 \times 10^8\ sec}{1}\right)\left(\frac{1\ day}{86{,}400\ sec}\right) = 6.99 \times 10^3\ day$$

$$= \boxed{6{,}990\ days} = \boxed{19.15\ years}$$

(A) - calculate gradient in ft/m & ft/ft

6331 ft → 4200' Δ = 2131' = y

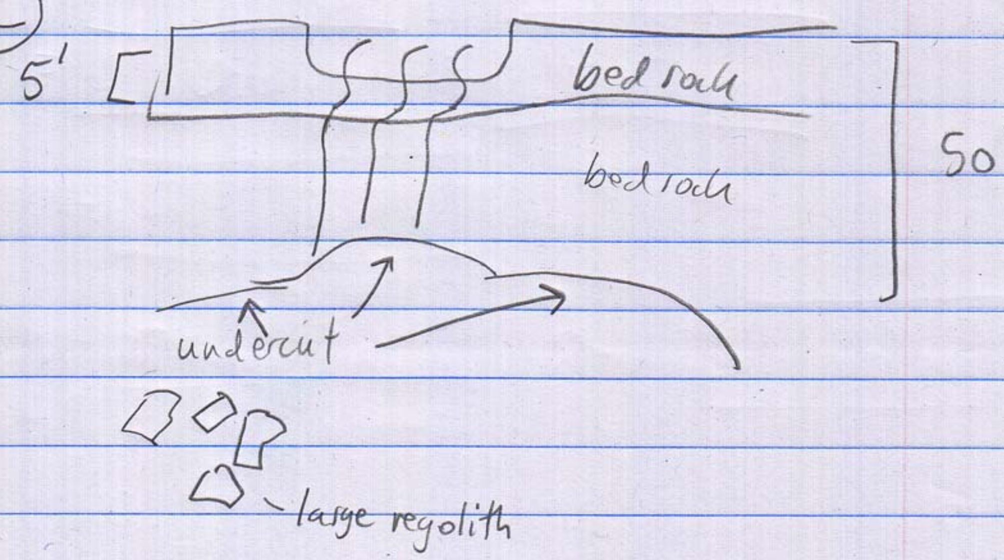
x = 13.5 m' = 71,280'

gradient = $\frac{\Delta y}{\Delta x} = \frac{2131'}{71,280'} = \boxed{0.03}\ \boxed{ft/ft}$

$\frac{\Delta y}{\Delta x} = \frac{2131'}{13.5\,mi} = \boxed{\frac{157'}{mile}}$

(B) We can't do this - we didn't take the time, I'm not there now.

(C)



- Comment and discuss whether the Deschutes River is associated with average, below average, or above average incision rates compared to other published studies?

- List and discuss the variables that control the incision rate of any given drainage basin?

Part 4 - Deschutes Basin Water Budget Analysis

Refer to the location map of the Deschutes River basin on p. 232 of the field guide. The total drainage area of the basin is 27,200 sq. km. The Deschutes is climatically and physiographically divided into two distinct sub-regions, the wetter western portion comprised of the High Cascades (covering about 10% of the total basin area), and the drier eastern portion comprised of the Ochoco Mountains, Newberry Volcano, and High Lava Plains (covering about 90% of the total basin area). The western (Cascades) portion receives an annual average precipitation of 1500 mm/yr, while the eastern area receives approximately 250 mm/yr. In addition, the average annual discharge of the Deschutes River at its outlet near the Columbia River gorge is on the order of 175 m^3/sec. Your task is to conduct a cursory hydrologic analysis of the Deschutes watershed, based on the following questions:

A. Calculate the hydrologic parameters listed in the table below (show all of your math work and unit algebra):

Sub-area of western portion (sq. km) 27,200 x .10 sq. m 2720 X 10^6

Sub-area of eastern portion (sq. km) 27200 x .90 sq. m 24480 X 10^6

Average annual precipitation western (in/yr) 1500 mm x 1 cm / 10 mm x 1 inch / 2.54 cm = 59.05 ≅ 59"/yr

Average annual precipitation – eastern (in/yr) 250 mm x 1 cm / 10 mm x 1 inch / 2.54 cm = 9.8" ≅ 10"/yr

Average annual precipitation – western (m/yr) 1500 mm / 1000 mm · m = 1.5 m/yr

Average annual precipitation – eastern (m/yr) 250 / 1000 = .25 m/yr

Total Precipitation Input Volume for Year – Eastern (cu. m) (.25)(24480 X 10^6) 6.12 X 10^9 m^3

Total Precipitation Input Volume for Year – Western (cu. m) (1.5 m/yr)(2720 X 10^6 m^2) 4.08 X 10^9 m^3

Total River Discharge Output Volume for Year – at Outlet (cu. m) 175 m^3/sec X = 5.518 X 10^9

Total Annual Precipitation Input – Total Discharge Output (cu. m) 10.2 X 10^9 m^3 – 5.518 X 10^9 = 4.7 X 10^9 m^3

Total Annual Percent Loss of Precipitation During Drainage Process (cu. m) = [illegible]

4.7 / 10.2 = 46%

wrong doover!

(A-) (E) $27,200\ Km^2 \times (.10) =$ $2720 \times 10^6\ m^2$ East

(W) $27200\ km^2 (.90) =$ $24480 \times 10^6\ m^2$ West

(W) $\frac{(1500mm)(1cm)}{10mm} \times \frac{1\ in}{2.54cm} =$ $59.05\ in/yr.$ west Av precip

(E) $\frac{(250\ mm)(1cm)}{10mm} \times \frac{1\ in}{2.54cm} =$ $9.8\ in/yr$ east av precip

(W) $\frac{1500\ mm}{yr.} \cdot \frac{m}{1000\ mm} =$ $1.5\ m/yr.$ Av prec. W

(E) $\frac{250\ mm}{yr} \cdot \frac{m}{1000\ mm} =$ $0.25\ m/yr$ Av prec E

(E) $\left(\frac{0.25\ m}{yr}\right)\left(2720 \times 10^6\ m^2\right) = 680 \times 10^6\ m^3$

Total rain/yr. East

$= 6.8 \times 10^8\ m^3$

(W) $\left(\frac{1.5\ m}{yr}\right)\left(24480 \times 10^6\ m^2\right) = 36720 \times 10^6\ m^3$

$= 3.7 \times 10^{10}\ m^3$

Total Rain/yr West

Total Disch Q_{annual}

$$\left(\frac{175\,m^3}{sec}\right)\frac{60\,sec}{min}\cdot\frac{60\,min}{hr}\cdot\frac{24\,hr}{day}\cdot\frac{365\,days}{yr}$$

$$= \boxed{5.52 \times 10^9\ m^3/yr}$$

Annual Precip − Q_{annual} = m^3

East $(6.8 \times 10^8\,m^3)$

+West $(3.7 \times 10^{10}\,m^3)$

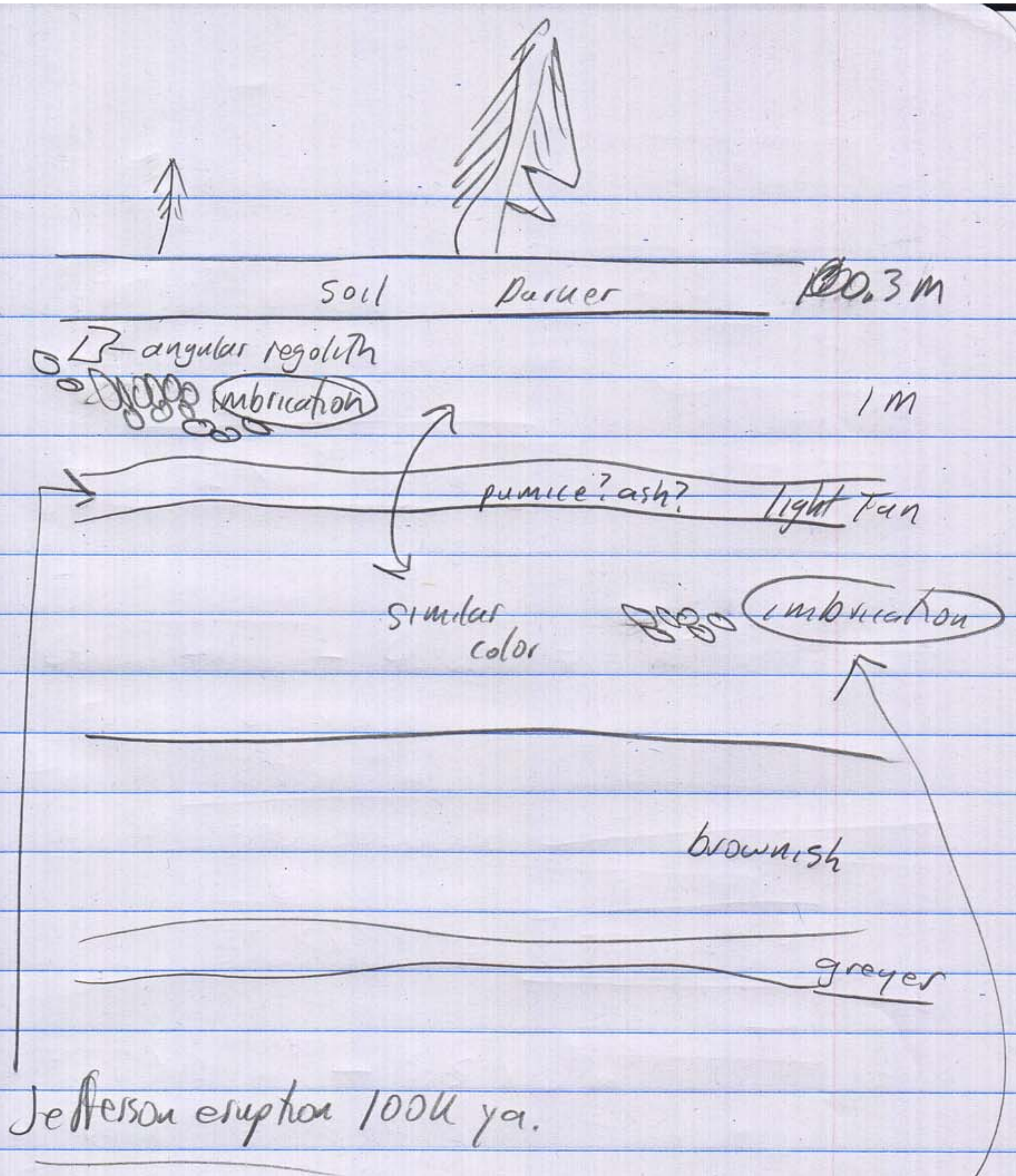
$$\begin{array}{r} 37000000000 \\ 680000000 \\ \hline 3768 \times 10^7 \end{array} = \boxed{3.77 \times 10^{10}\ m^3}$$

Total Annual Precip

$$\left[\underset{rain}{3.77 \times 10^{10}\ m^3/y}\right] - \left[\underset{output}{5.5 \times 10^9\ m^3/y}\right]$$

$$= \begin{array}{r} 37700000000 \\ 5.5 \\ \hline 322 \times 10^8 \end{array} = \boxed{3.22 \times 10^{10}\ m^3\ \text{LOST}}$$

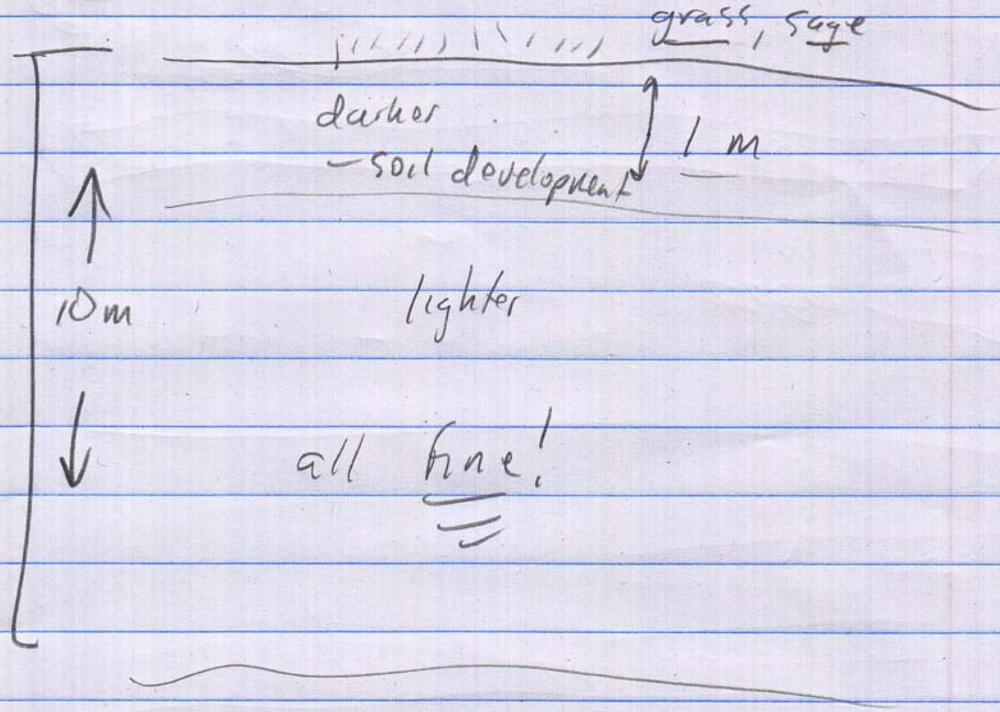
$$\% = \frac{3.22 \times 10^{10}\ \text{LOST}}{3.77 \times 10^{10}\ \text{Total}} = .85 = \boxed{85\%}$$



This is a series of terraces or perhaps actual river bed - as indicated by the imbricated, rounded gravels. The upper layer is soil - last 10's of Thousands of years. The layer from the ash to surface is 100,000 years old to Present, using Jefferson Layer!

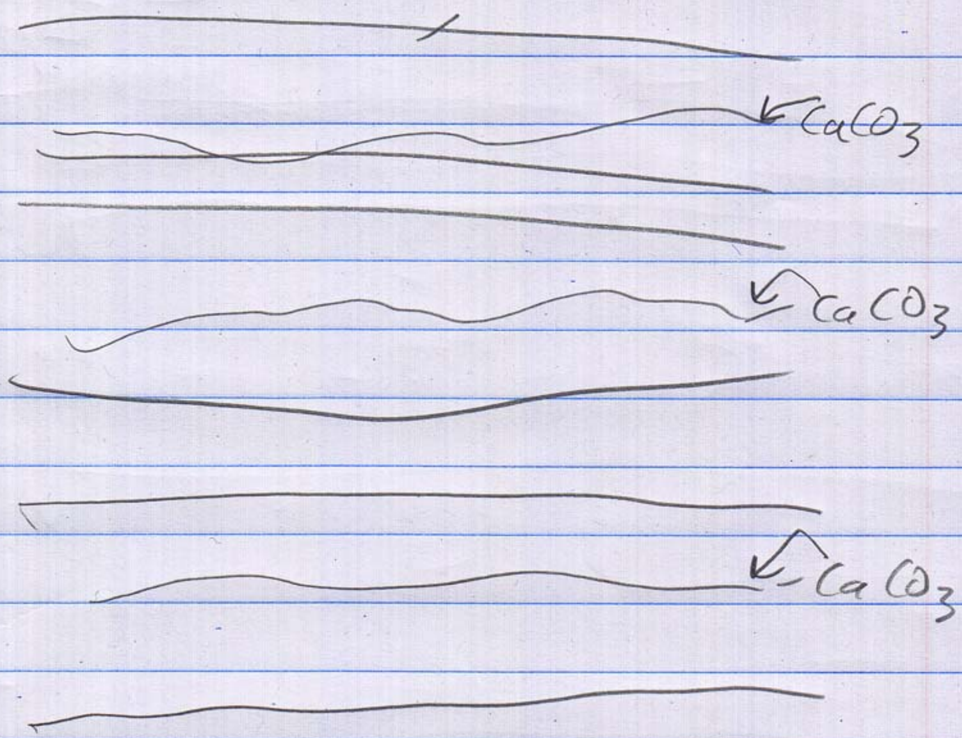
Road Cut 197

Loess or Missoula Deposit



This is loess or ~~the~~ transported Loess from Missoula Flood. Could be loess blown by catabatic winds from Cordillran Sheet / Okonagan lobe. ~~Sandwiched~~ (Left to right) between Dalles formation bedrock.

Other cuts - 197 - generally



17-7 Ma - about same age as CRB's.
Dalles formation - uphill of the Loess Deposits. Mostly Light colors. Ignimbrite - tuffaceous, ashy deposits - probably from ancestral cascades. Repeated layers of aridisols indicate paleosols - soil had time to develop between flows. Mt Hood only 35 mi away!