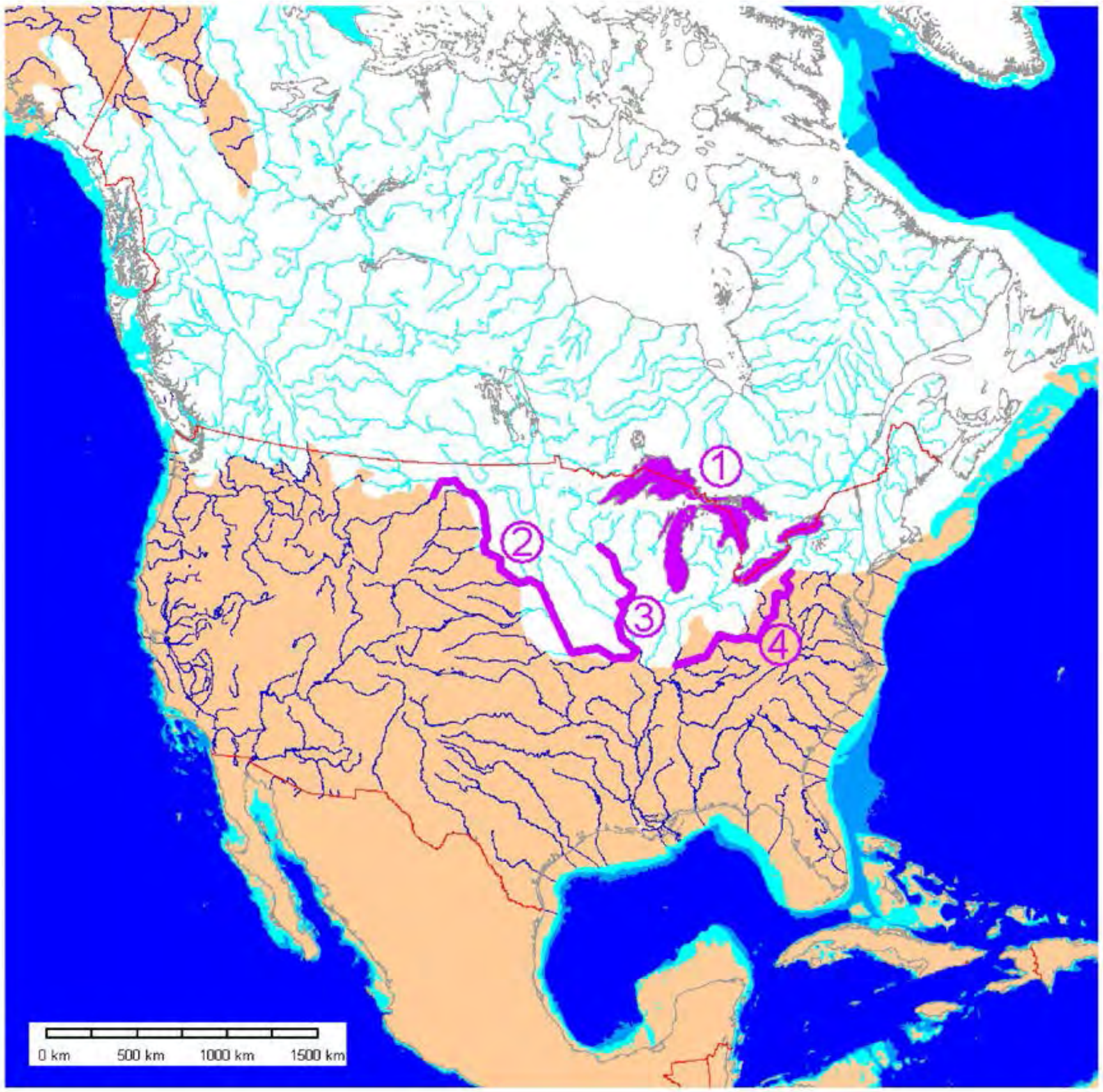
Pacific Northwest Quaternary Climate History: Very Short Version

2:00



Glacial Maximum North America

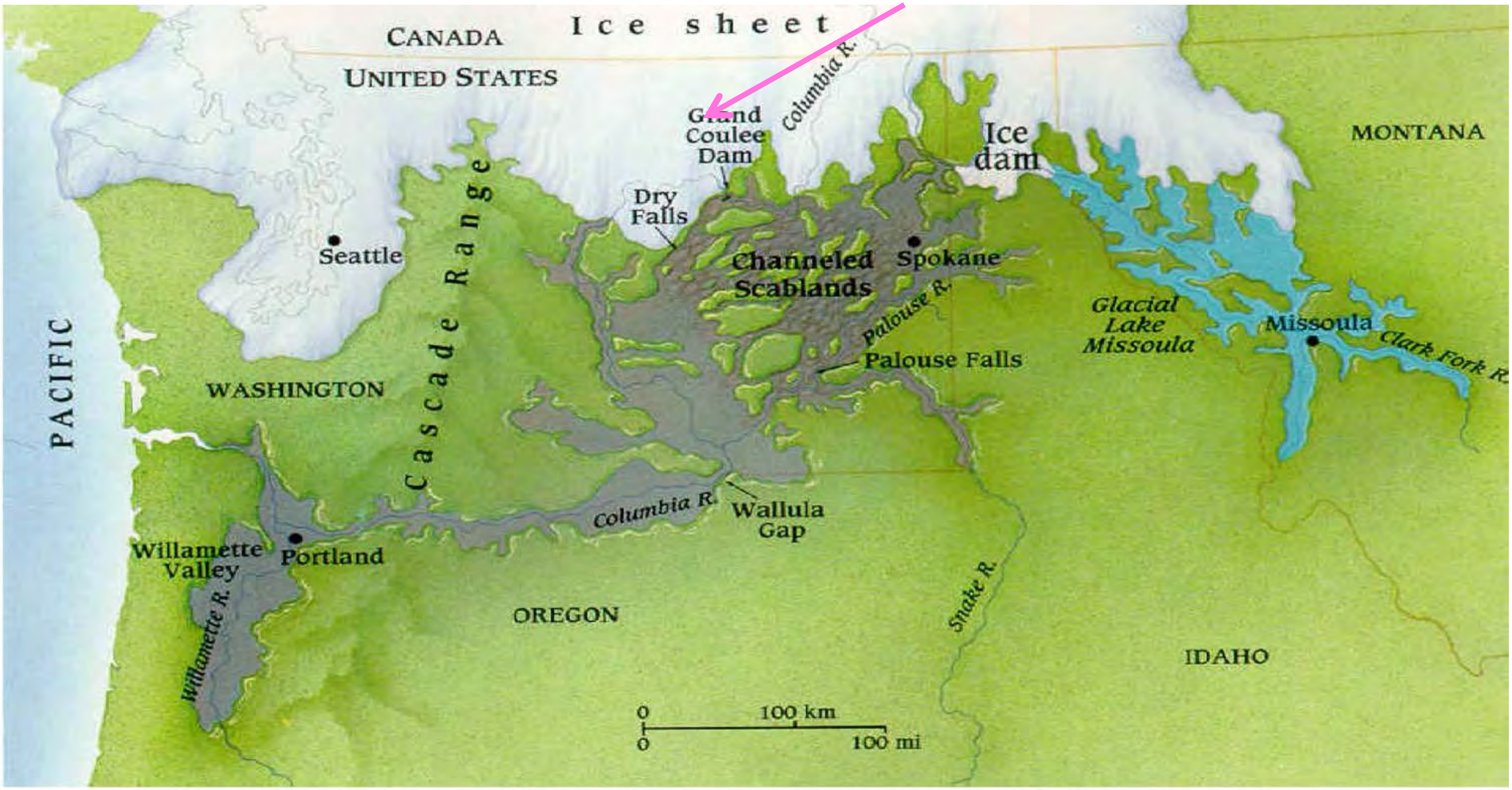
Major Effects:

1. Great Lakes

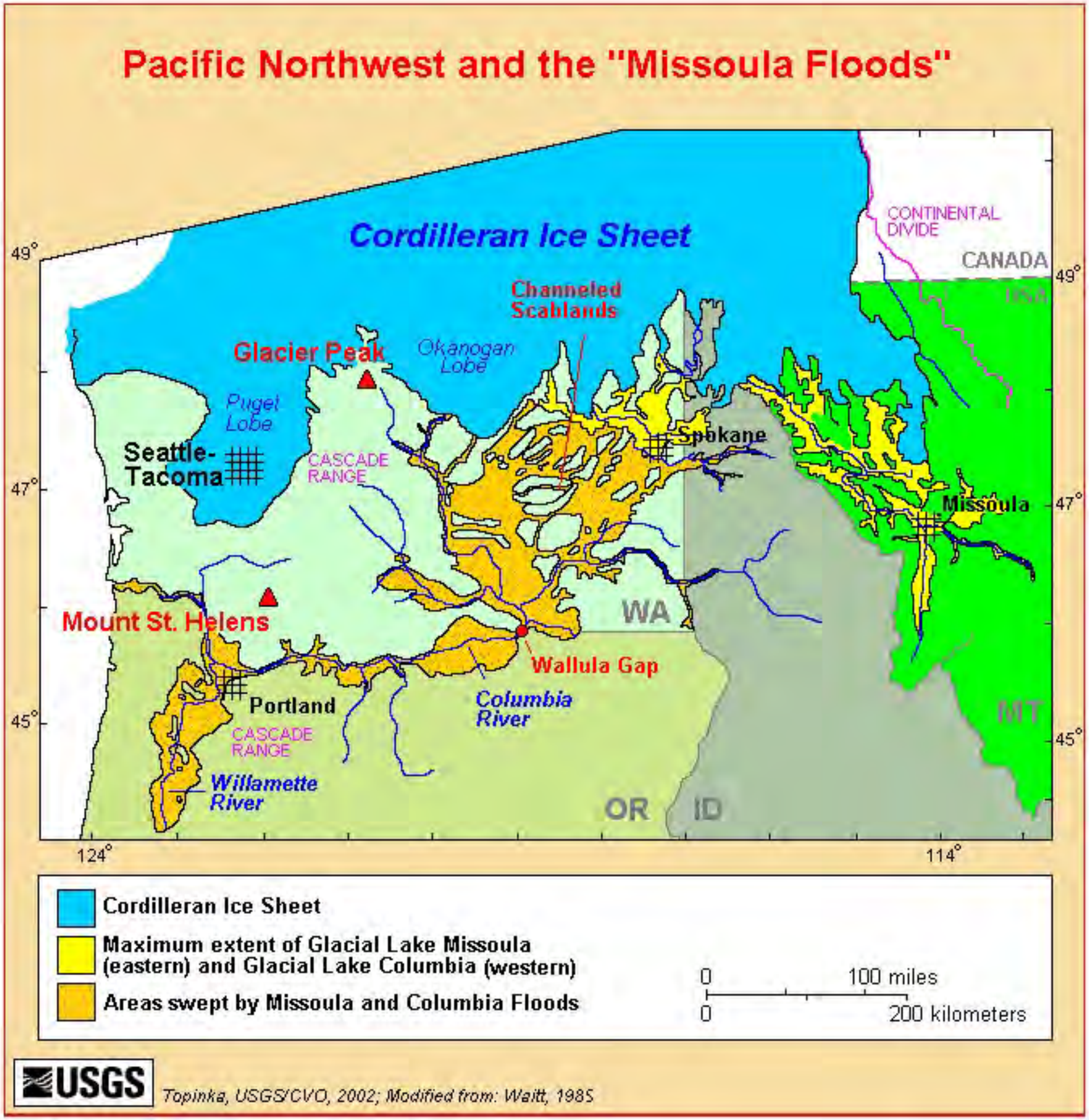
2. Missouri River Drainage

3. Upper Mississippi River Drainage

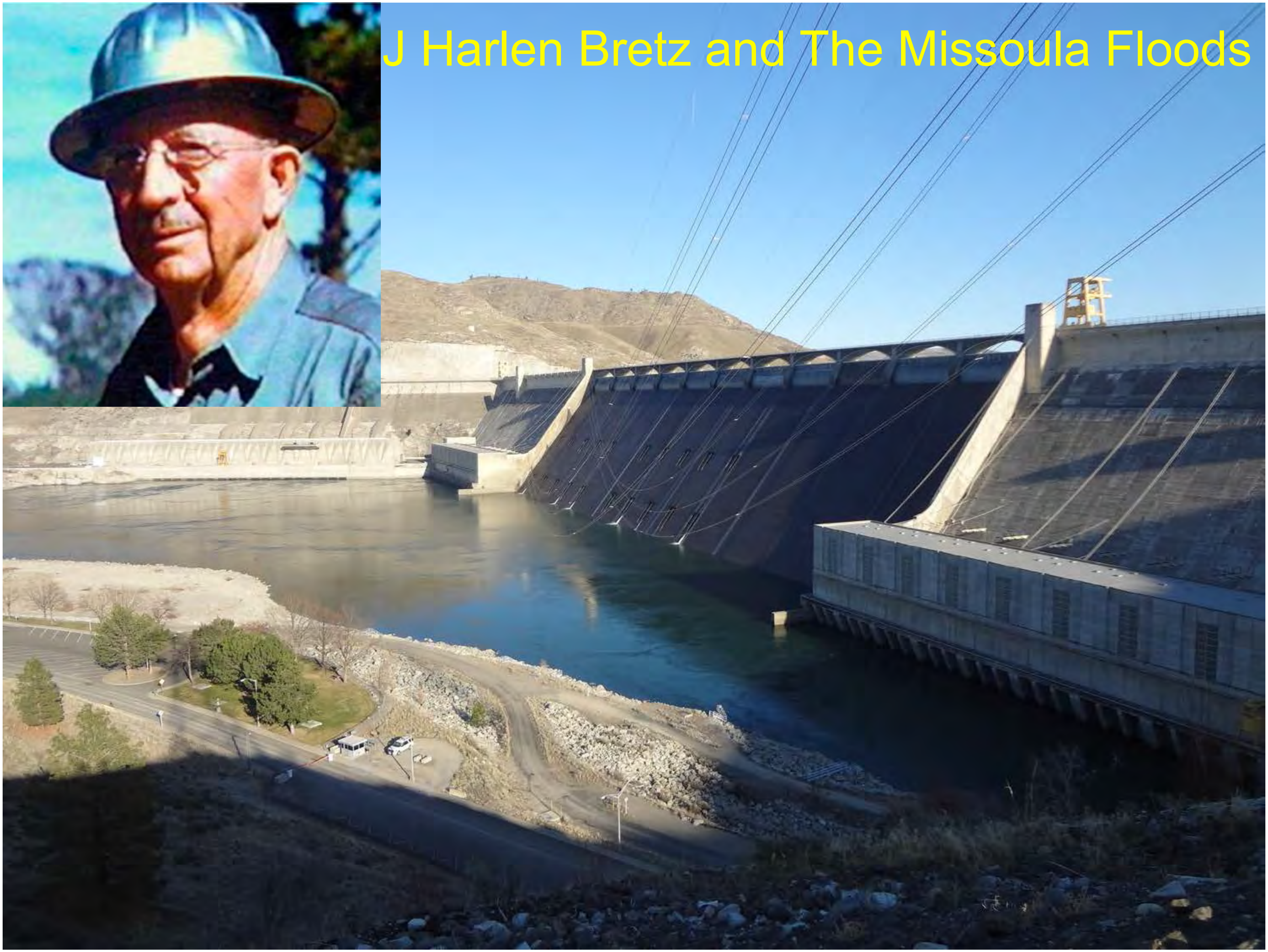
3. Ohio River Drainage

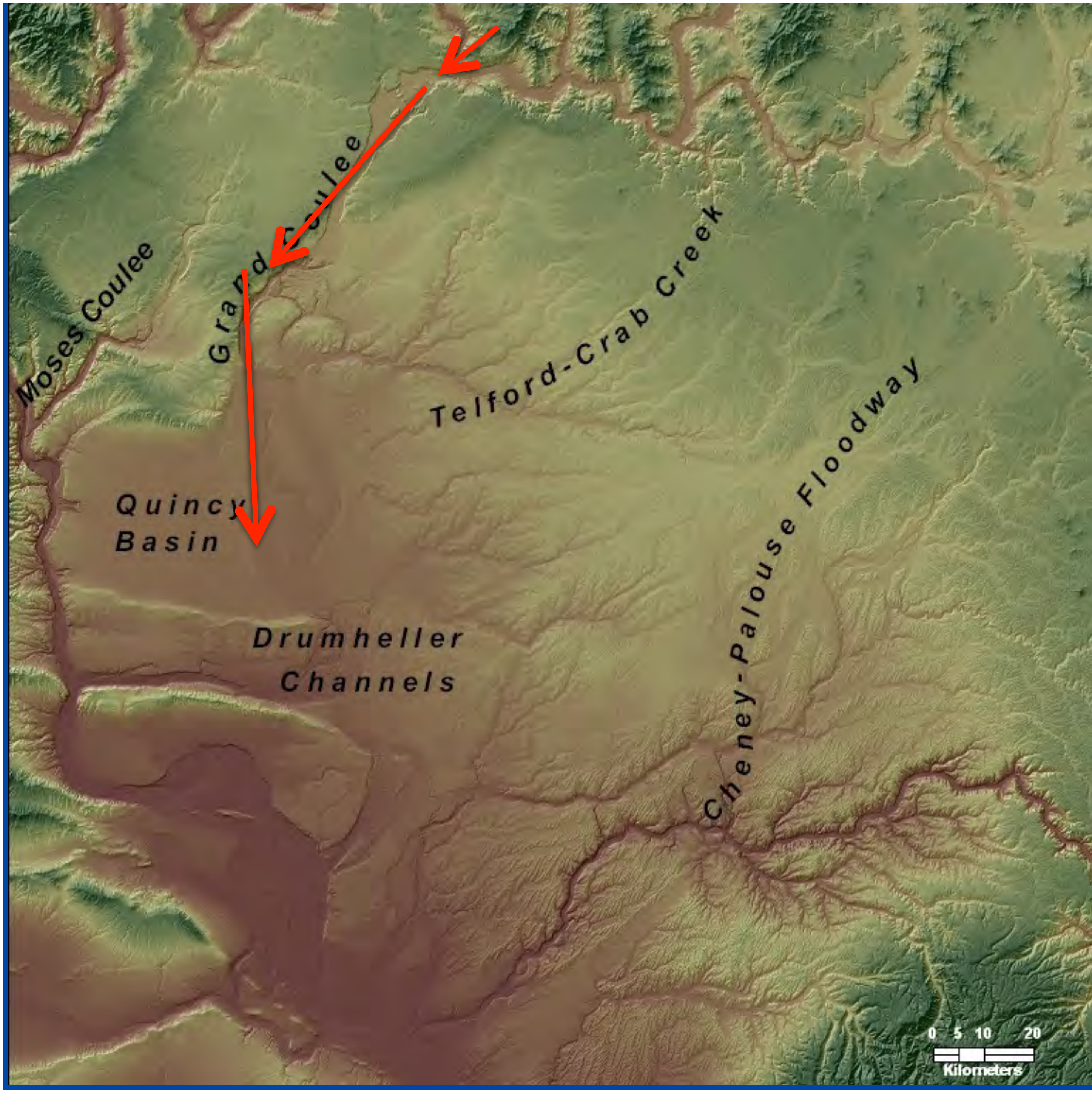


Columbia Ice Sheet at glacial maximum.
Area of Missoula Flood inundation


Pacific Northwest and the "Missoula Floods"
Cordilleran Ice Sheet
CONTINENTAL DIVIDE
CANADA
USA
Channeled Scablands
Glacier Peak
Okanogan Lobe
Puget Lobe
Seattle-Tacoma
CASCADE RANGE
Spokane
Missoula
Mount St. Helens
WA
Wallula Gap
Portland
Columbia River
CASCADE RANGE
Willamette River
OR
ID
MT
49°
47°
45°
124°
114°
Cordilleran Ice Sheet
Maximum extent of Glacial Lake Missoula (eastern) and Glacial Lake Columbia (western)
Areas swept by Missoula and Columbia Floods
0 100 miles
0 200 kilometers
USGS
Topinka, USGS/CVO, 2002; Modified from: Waitt, 1985

J Harlen Bretz and The Missoula Floods





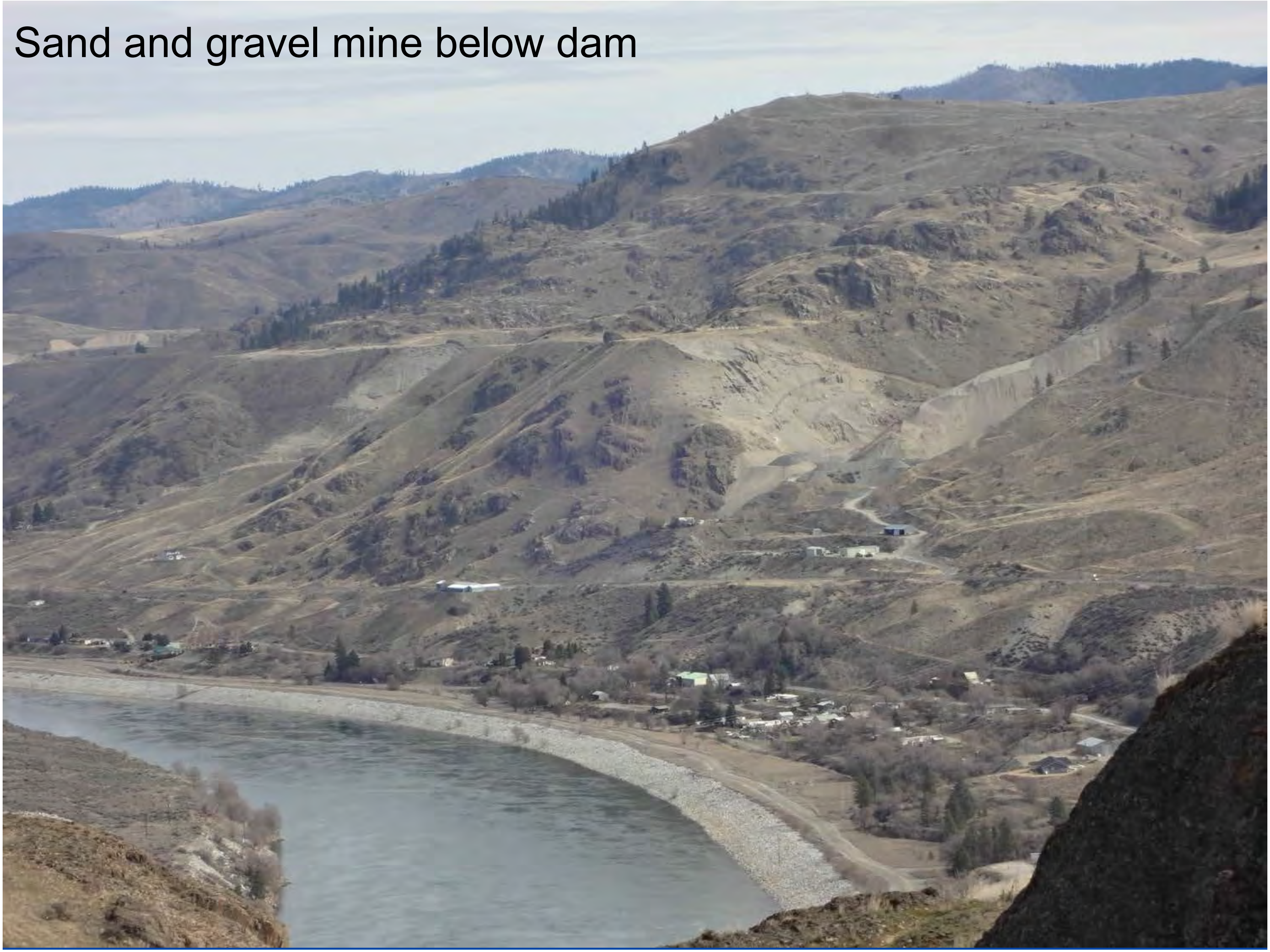
http://glaciers.us/jhbretz

Grand Coulee Dam

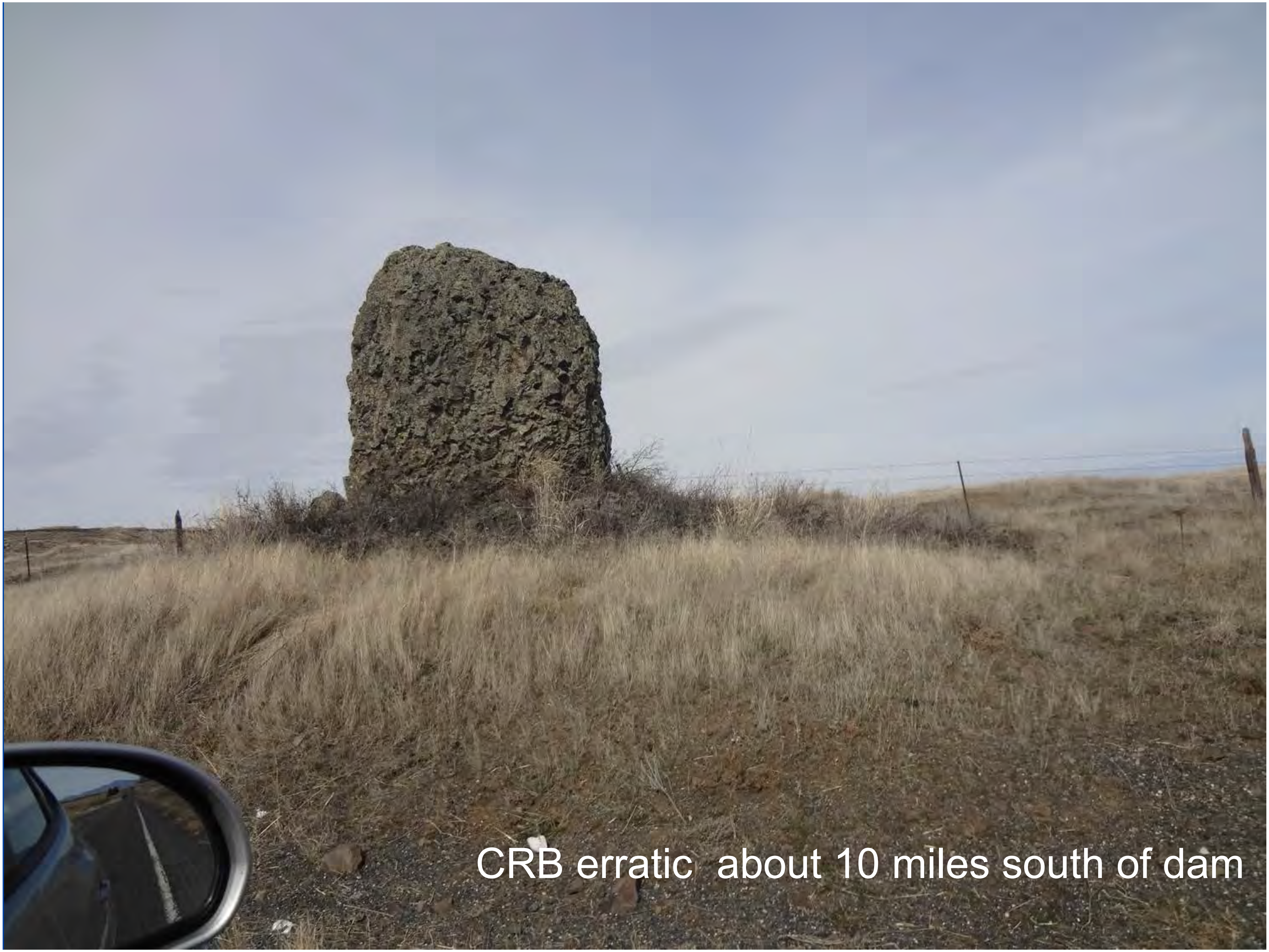
Just below Grand Coulee Dam

Grand Coulee downstream from dam

Sand and gravel mine below dam




Above Grand Coulee Dam, south bank
Flood deposits in foreground, CRB on skyline


CRB erratic about 10 miles south of dam


Glacial erratics


Dry Falls


Dry Falls: note plunge pools

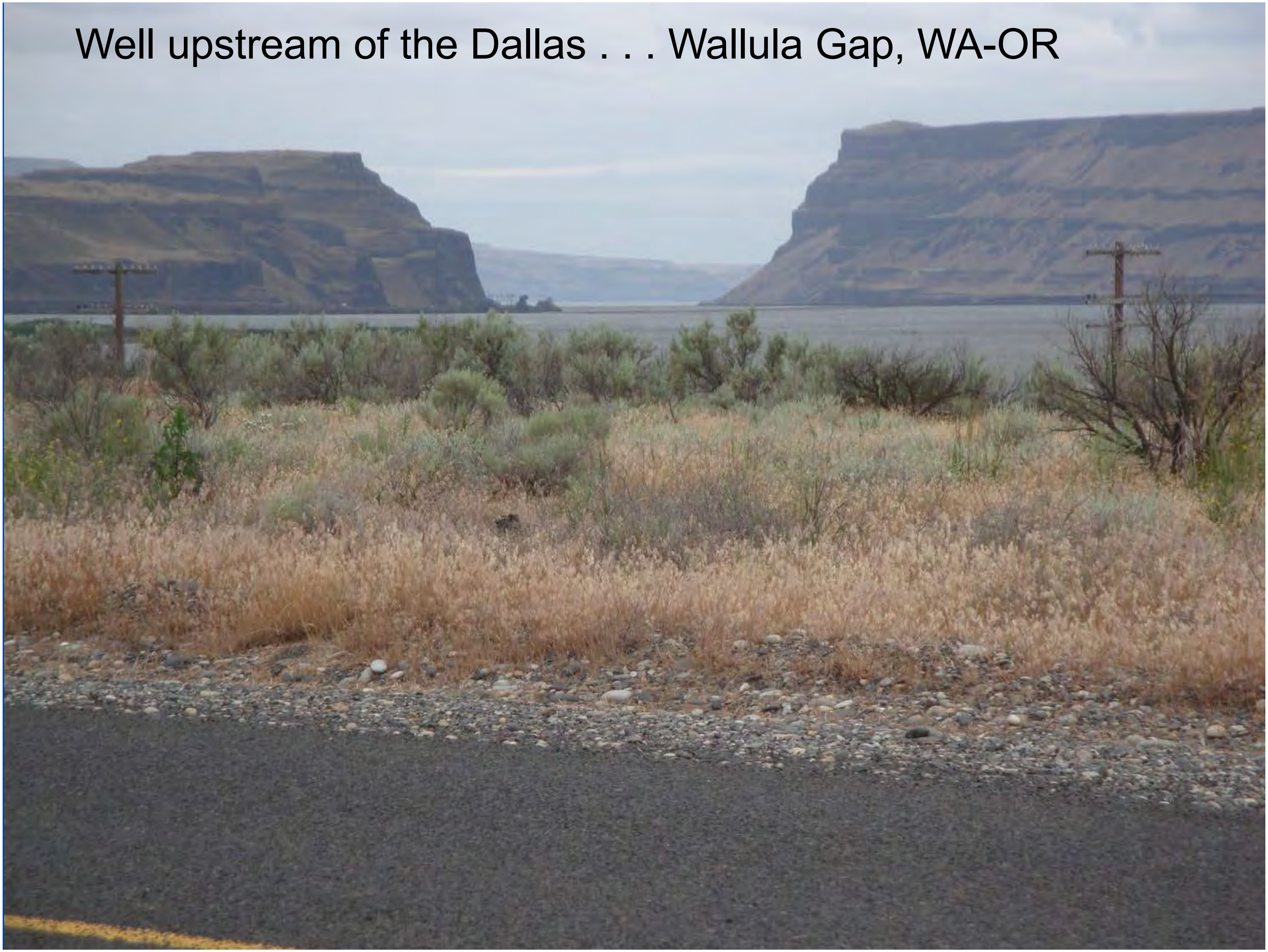
Coulee below Dry Falls

Dry Falls, Washington

Glacial gravels, East Quincy Basin

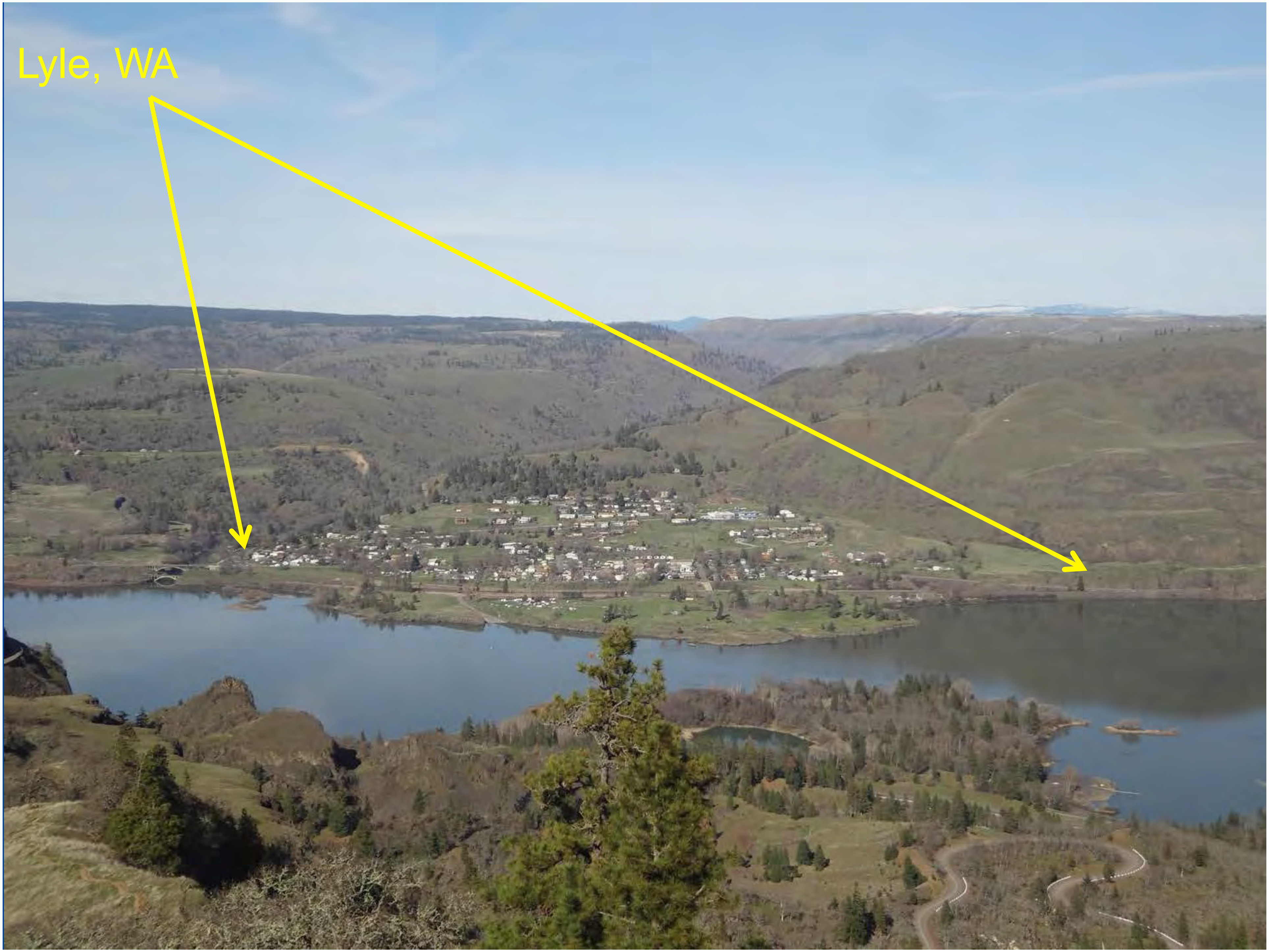
101
82
12
395
84
205
405
26
5
© 2016 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Google earth
Imagery Date: 4/9/2013 45°50'52.39" N 121°13'45.58" W elev 1267 ft eye alt 222.03 mi

Well upstream of the Dallas . . . Wallula Gap, WA-OR




Intervals of clean rock all along the Columbia River


Sand and Gravel mine, Dallasport, WA, Columbia River


Lyle, WA

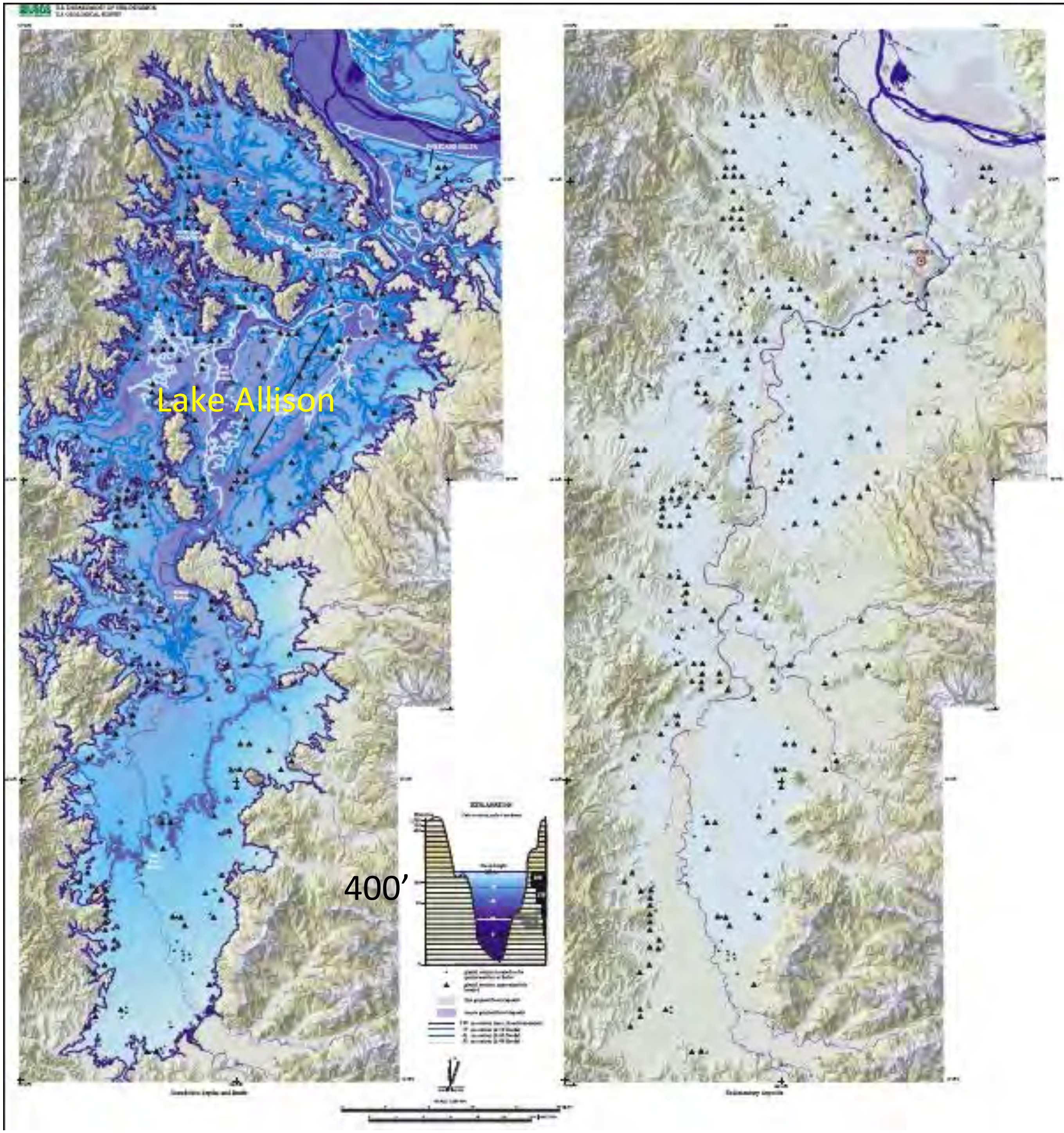

Somewhere well above the river . . .

. . . We find a deposit of young, unconsolidated sediments . . .


. . . Which are not derived from local sources. They are located over 300 feet above the river.


Nearby, one must ask: Where is the soil?


Sand and Gravel Mine, Ross Island



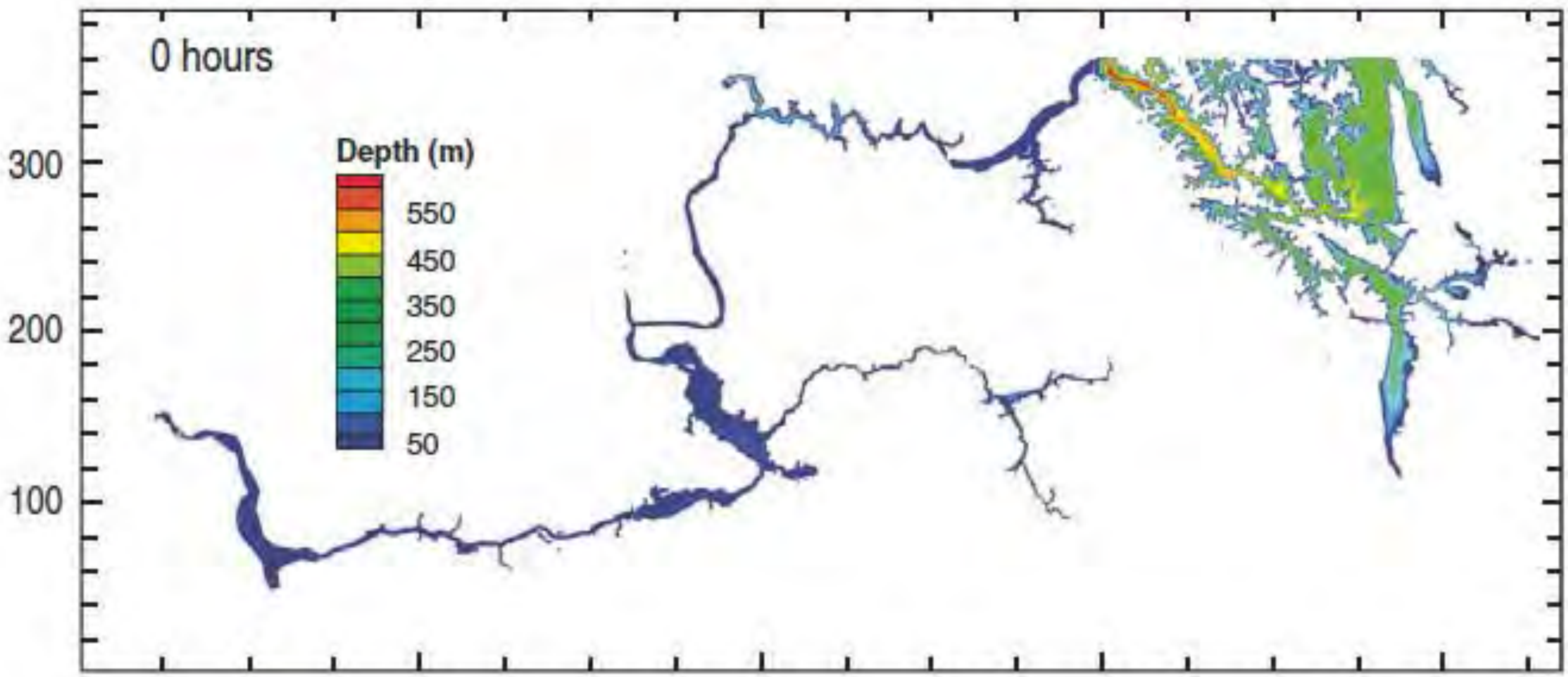
Missoula Flood

Innundation

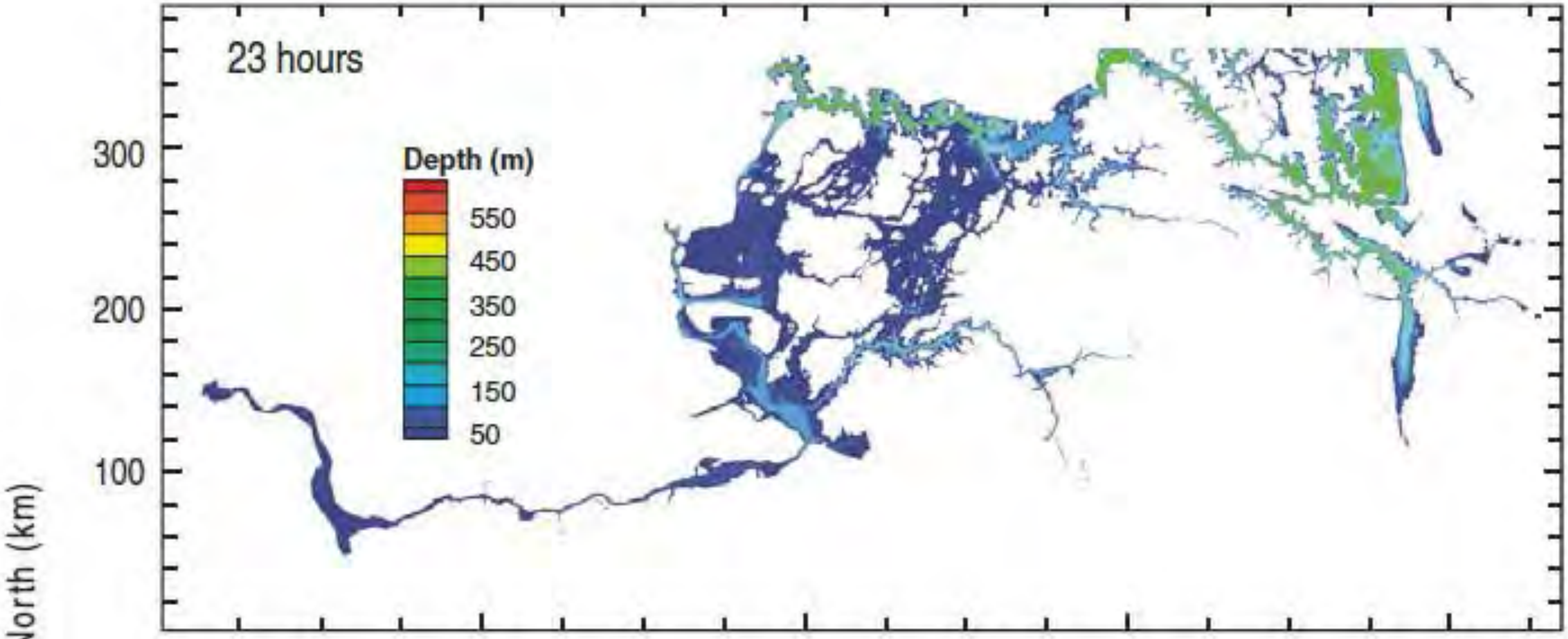
Depths,

Willamette

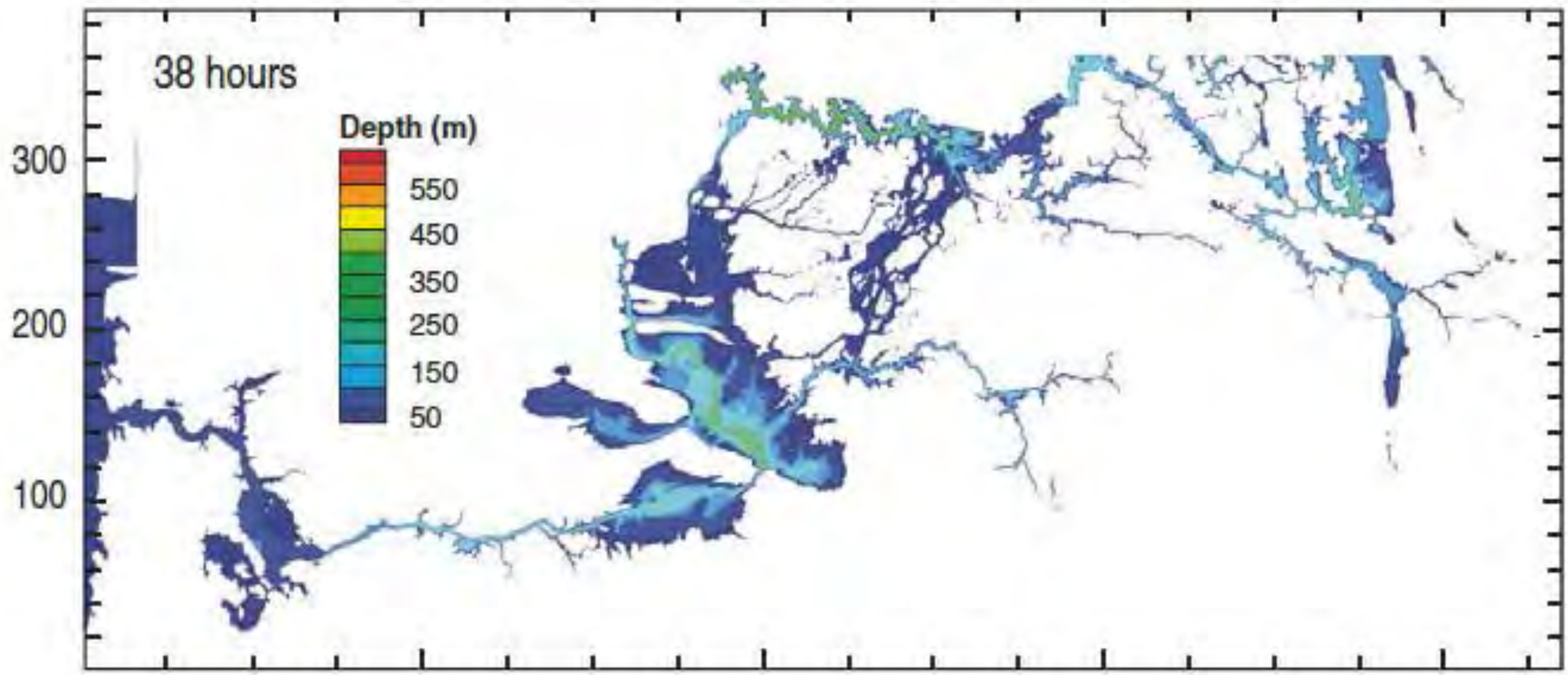
Valley



Denlinger and O’Connell 2010



Denlinger and O'Connel 2010



Denlinger and O'Connel 2010

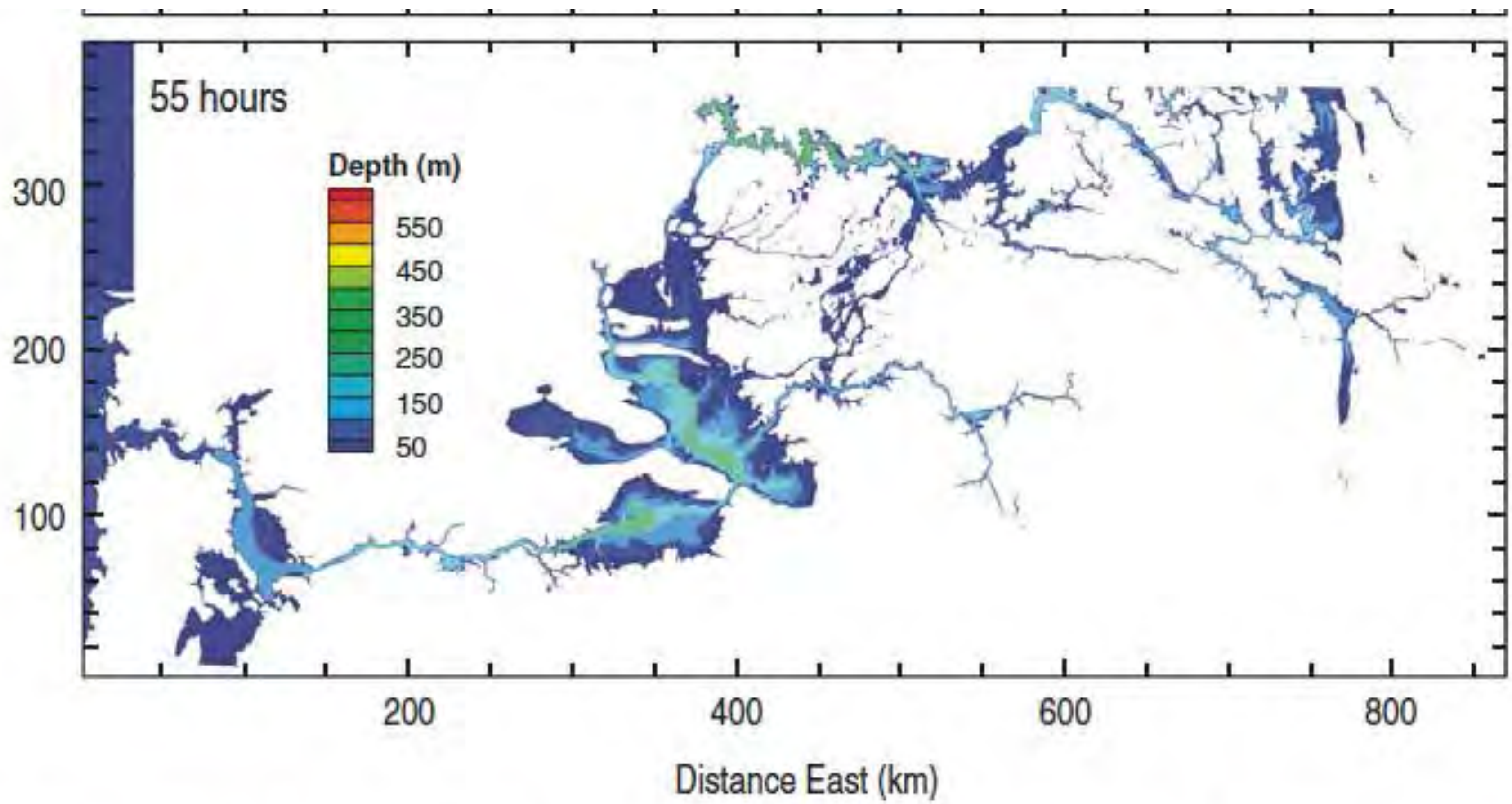
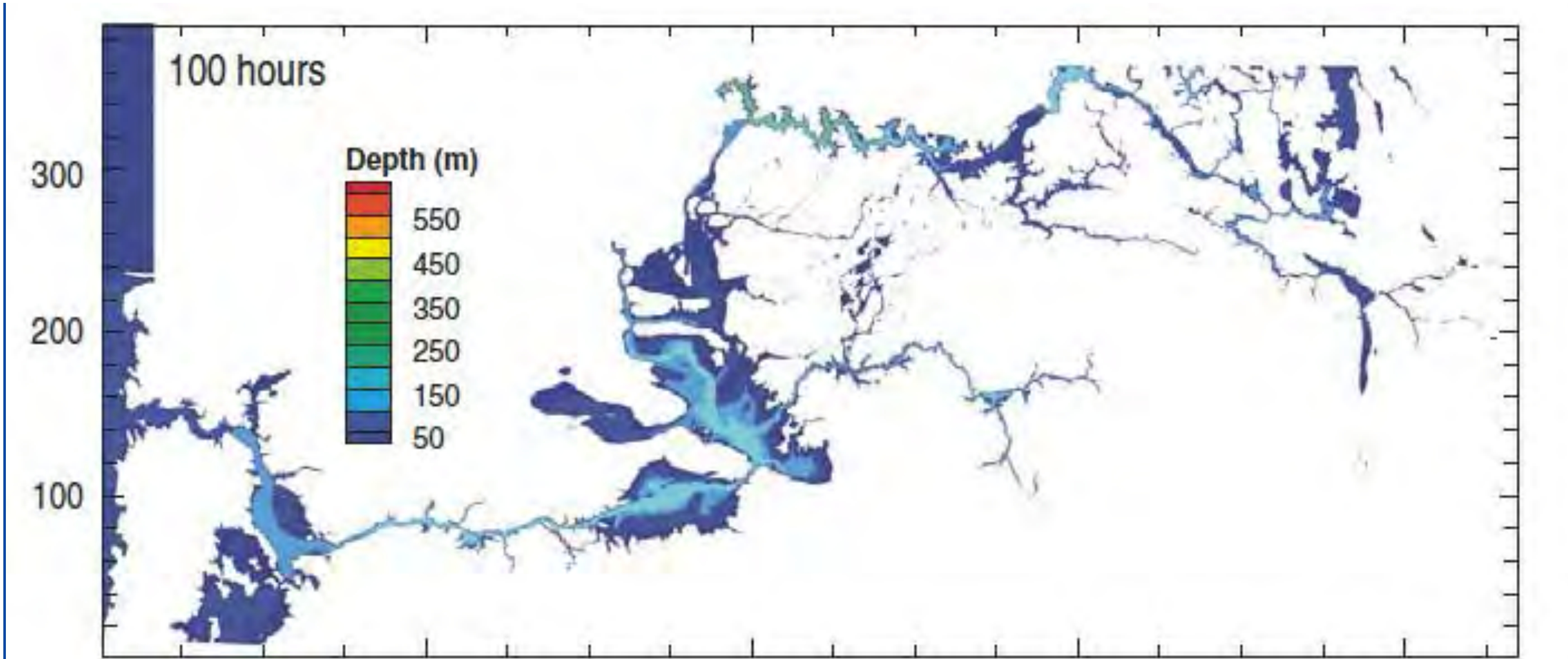


Figure 3. Flooding of eastern Washington from catastrophic rupture of the ice damming Glacial Lake Missoula was rapid and severe. Maximum inundation of the Channeled Scablands occurs 23 h after dam rupture, and this overland flow begins filling Pasco Basin a full day before flow is developed throughout the remainder of the Columbia River drainage system. Pasco Basin achieves maximum stage 38 h after dam break occurs, and maximum stage in Umatilla Basin and Walulla Gap (see Fig. 1) follows 17 h later.

Denlinger and O'Connell 2010



Denlinger and O'Connell 2010

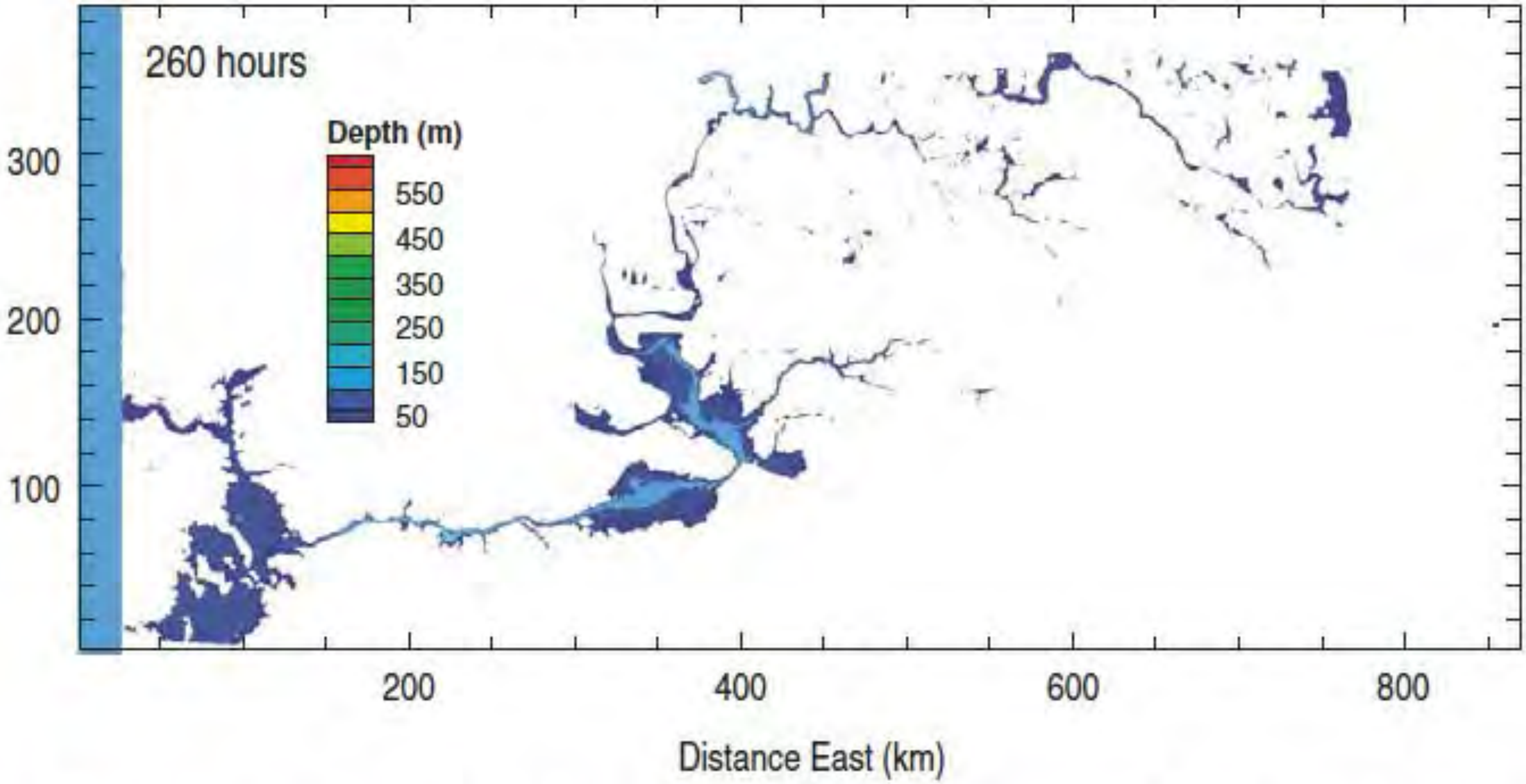


Figure 5. Drainage of Glacial Lake Missoula and the upper Columbia River system during a large Missoula flood. The broad basins of Pasco, Yakima, and Umatilla drain through Columbia gorge, extending the duration of flooding to 325 h. This long duration is primarily caused by the discharge limitation of the gorge, and secondarily by low gradients from the Willamette Valley to the Pacific Ocean in the final stages of flow.

Denlinger and O'Connell 2010

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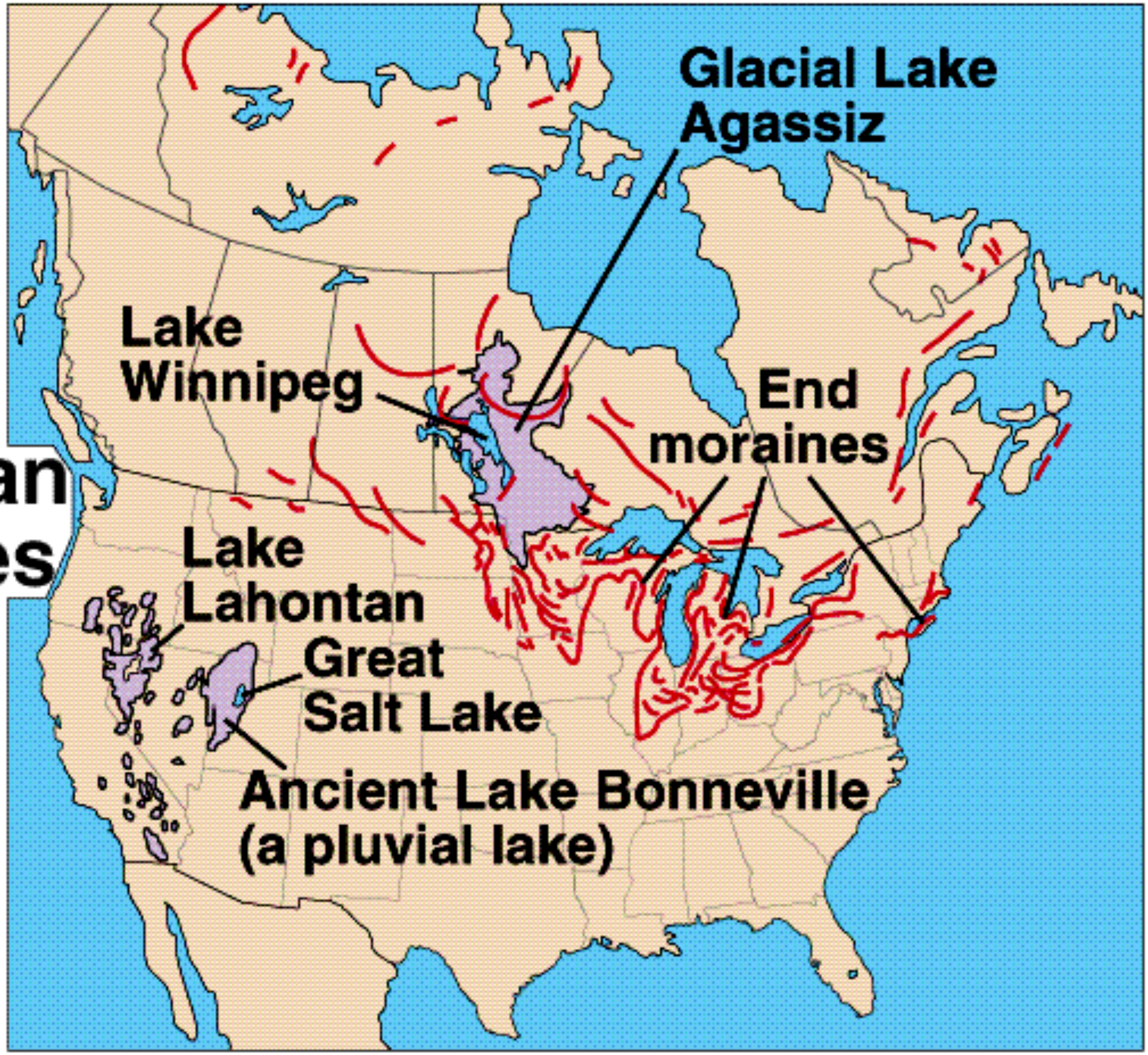
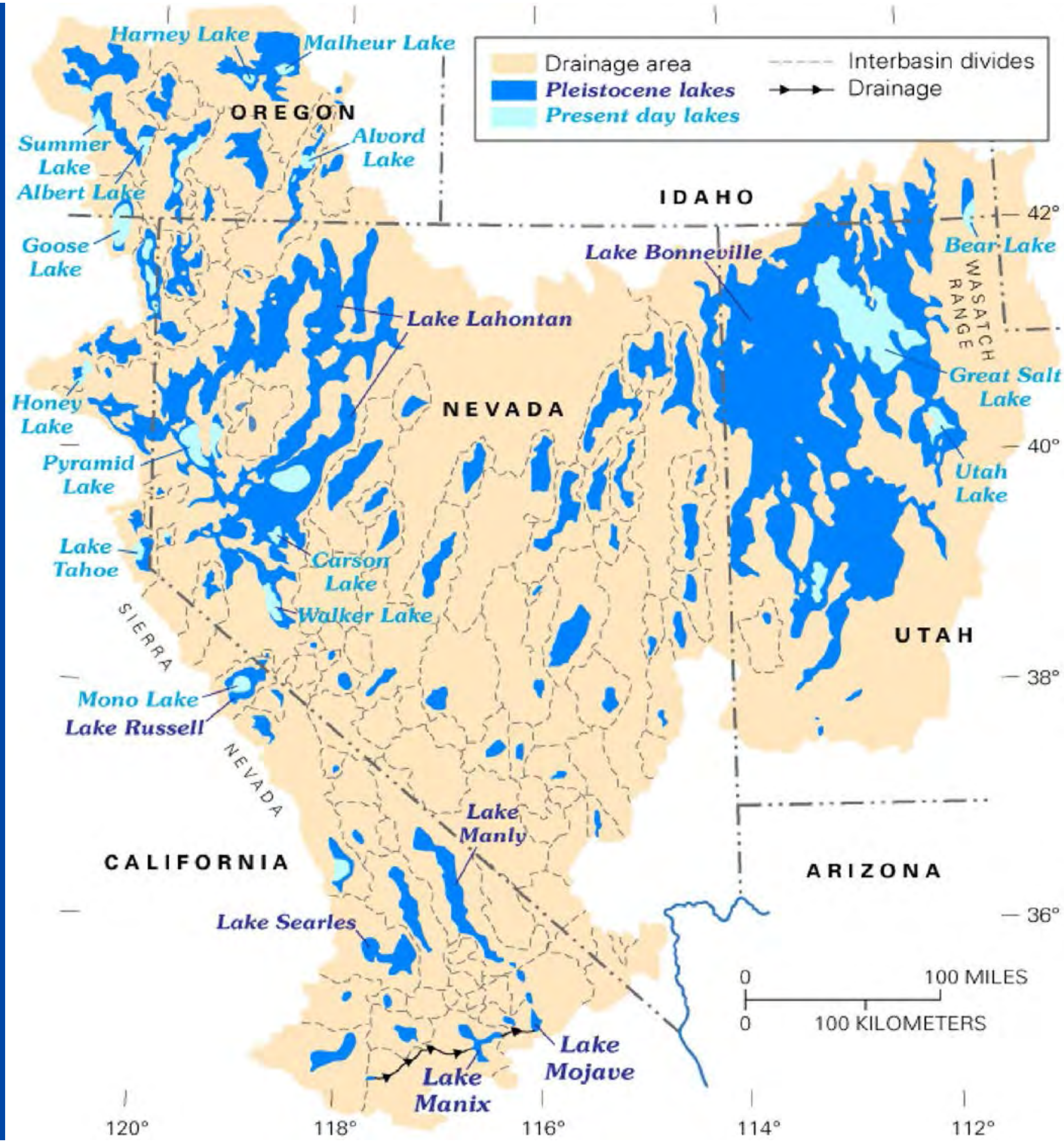
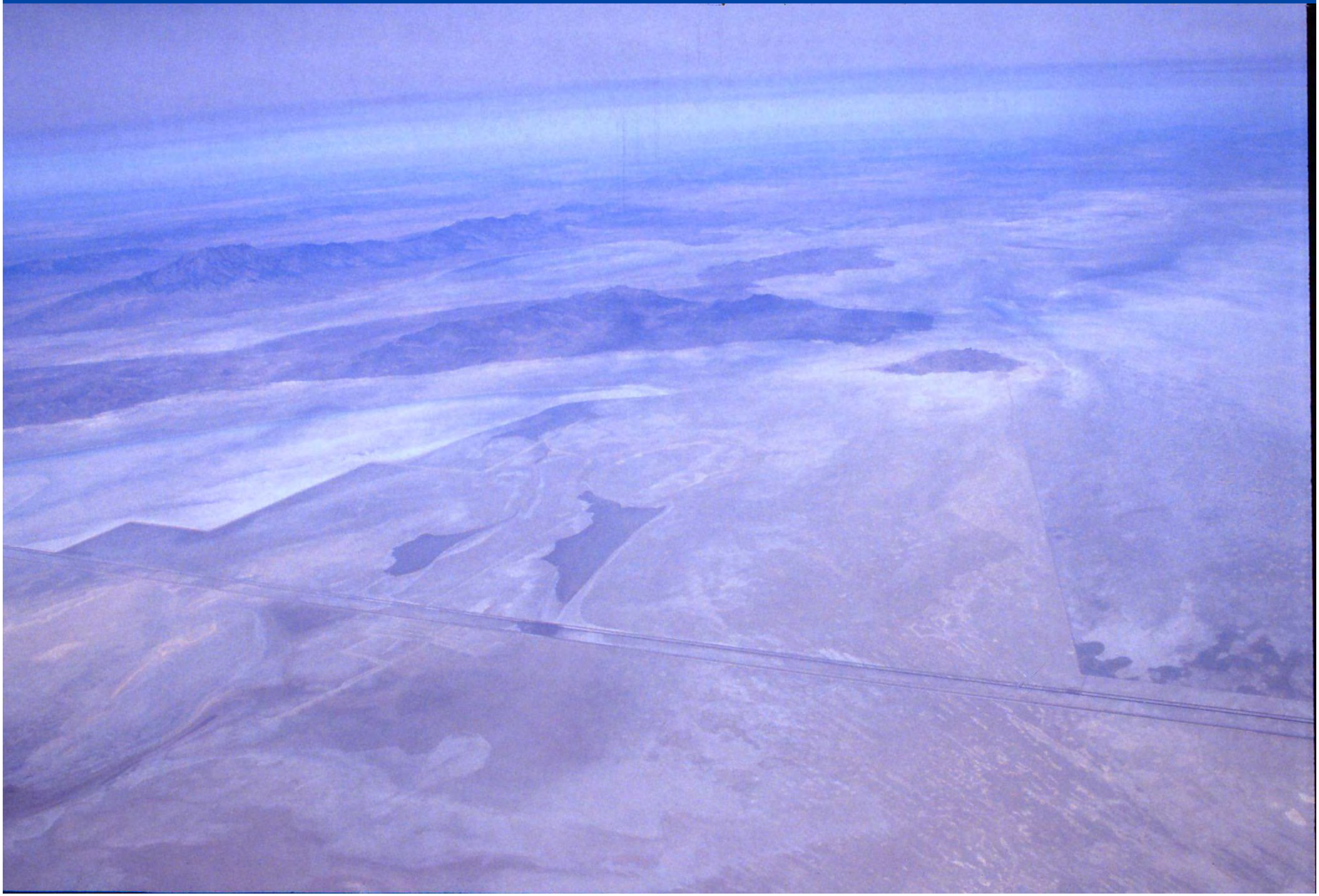
North American Moraines and Pluvial Lakes





Drainage area
Pleistocene lakes
Present day lakes
Interbasin divides
Drainage
Harney Lake
Malheur Lake
OREGON
Alvord Lake
Summer Lake
Albert Lake
Goose Lake
IDAHO
Lake Bonneville
Bear Lake
WASATCH RANGE
Great Salt Lake
Lake Lahontan
NEVADA
Honey Lake
Pyramid Lake
Utah Lake
Lake Tahoe
Carson Lake
Walker Lake
SIERRA NEVADA
UTAH
Mono Lake
Lake Russell
Lake Manly
CALIFORNIA
ARIZONA
Lake Searles
Lake Mojave
Lake Manix
0
100 MILES
0
100 KILOMETERS
42°
40°
38°
36°
120°
118°
116°
114°
112°

Lake Bonneville Salt Flats, Nevada-Utah



Pyramid Lake, NV

Pyramid Lake, Nevada: Where was Lake Lahontan highstand?

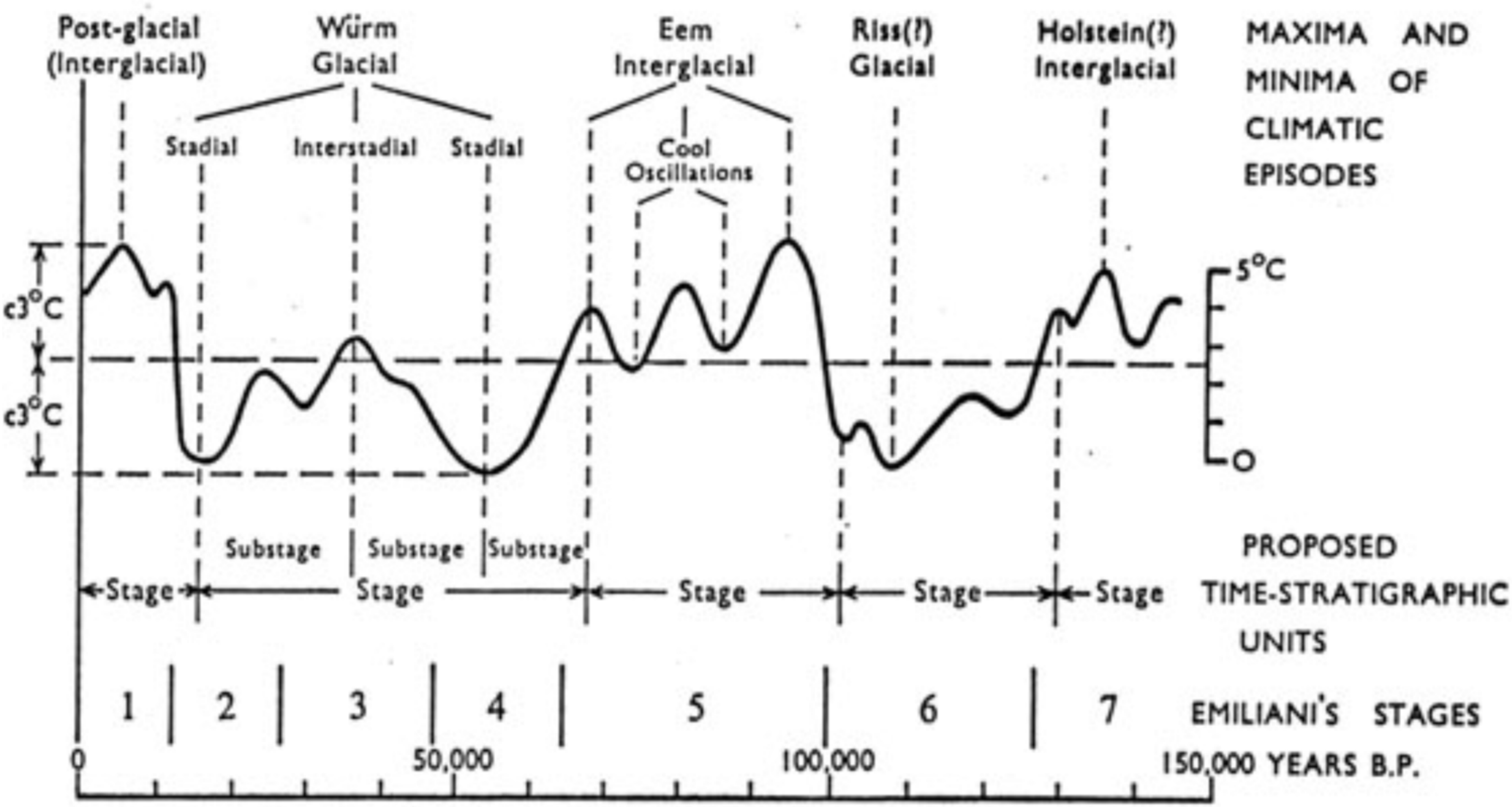

Summer Lake Basin, Oregon
71

Albert Lake, Hart Mountain, Oregon

Steens Mountain, Alvord Lake Basin, Oregon

Alvord Lake, Oregon


What Causes Glaciation?
Rhone Valley, Les Bossons, France



European Quaternary Glacial Stages

Major Climatic Forcing Mechanisms of the Sun - Earth Climate System

EXTERNAL

Solar Radiation and Galactic Forcing

- Sunspot variation and irradiance changes
- Solar ultraviolet wavelength variability
- Magnetic variation
- Celestial influence?

Earth's Orbital Changes

- Eccentricity
- Obliquity
- Precession of equinoxes

Asteroid Impacts

- Aerosols
- Extinction

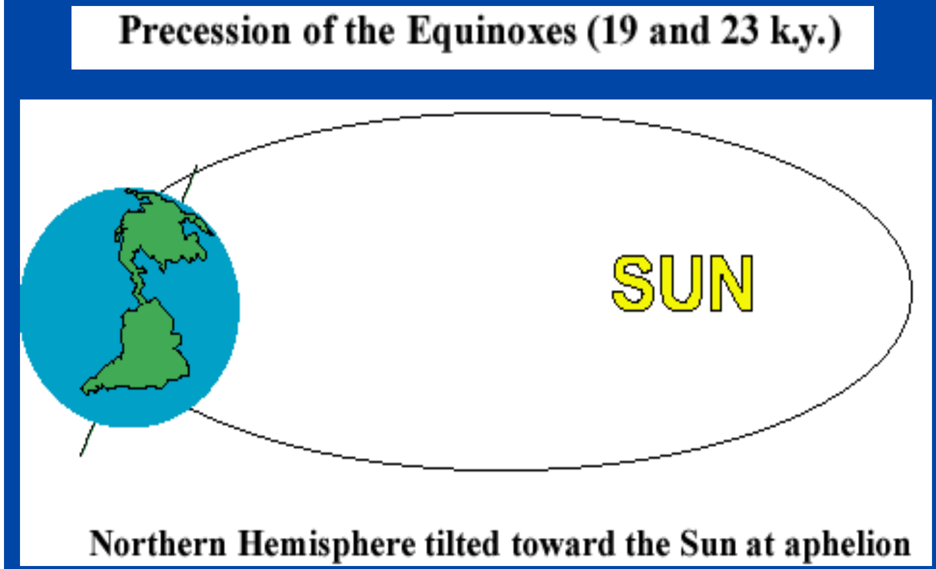
The Moon

- Gravity deflections
- Earth and ocean tides
- Biological rhythms

Slide courtesy of Art Green,Exxon)

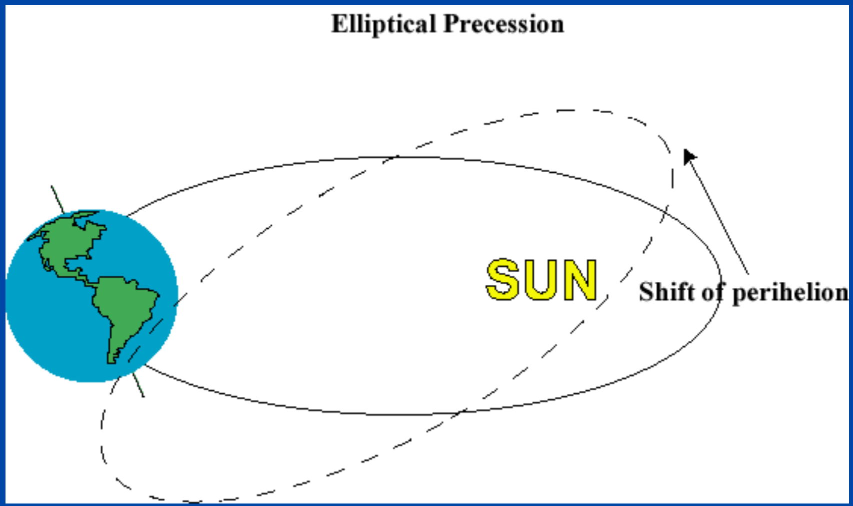
Orbital forcing: Milankovitch Theory

Precession: 19,000–23,000 years



The major axis of each planet's elliptical orbit also precesses within its orbital plane, in response to perturbations in the form of the changing gravitational forces exerted by other planets. This is called perihelion precession.

It is generally understood that the gravitational pulls of the sun and the moon cause the precession of the equinoxes on Earth which operate on cycles of 23,000 and 19,000 years.



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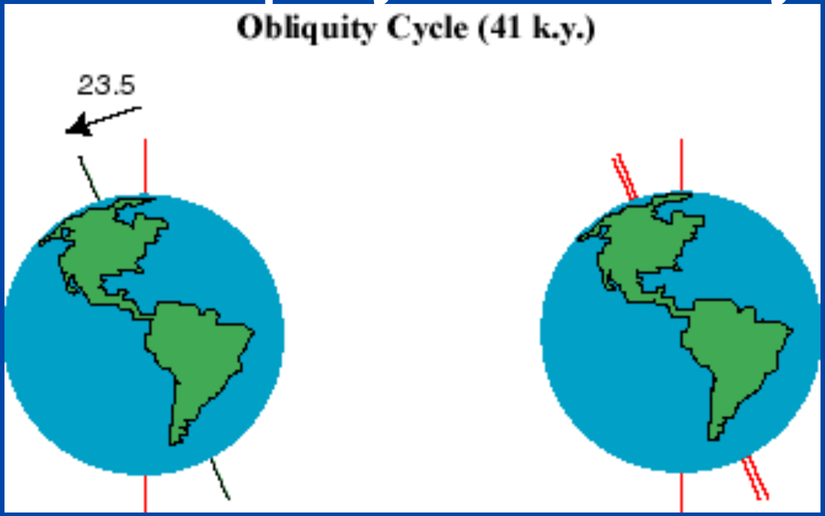
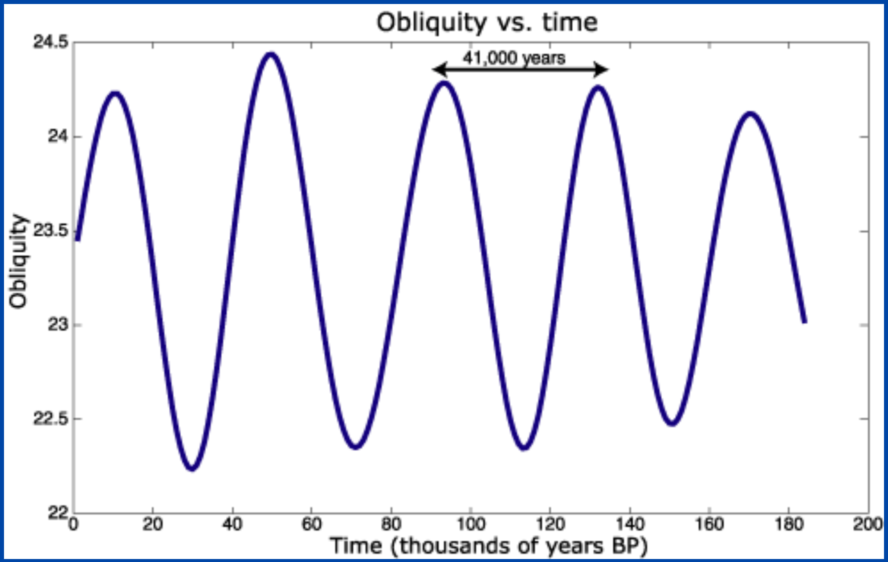
Orbital forcing: Milankovitch Theory

- Obliquity: 41, 000 yr cycle





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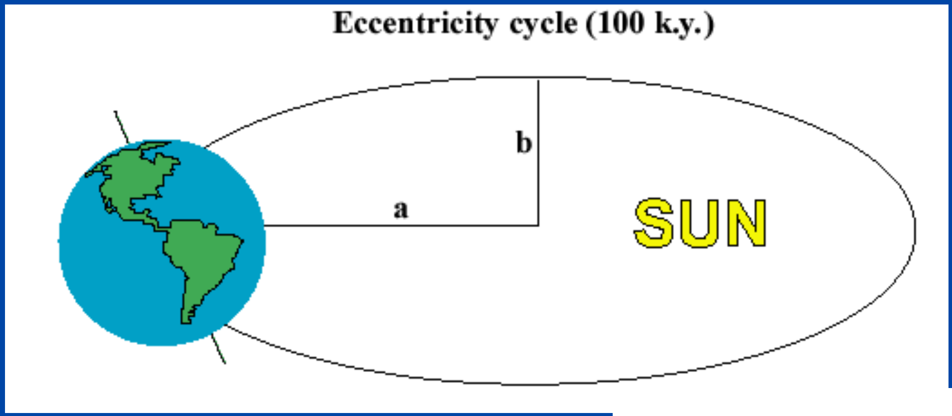
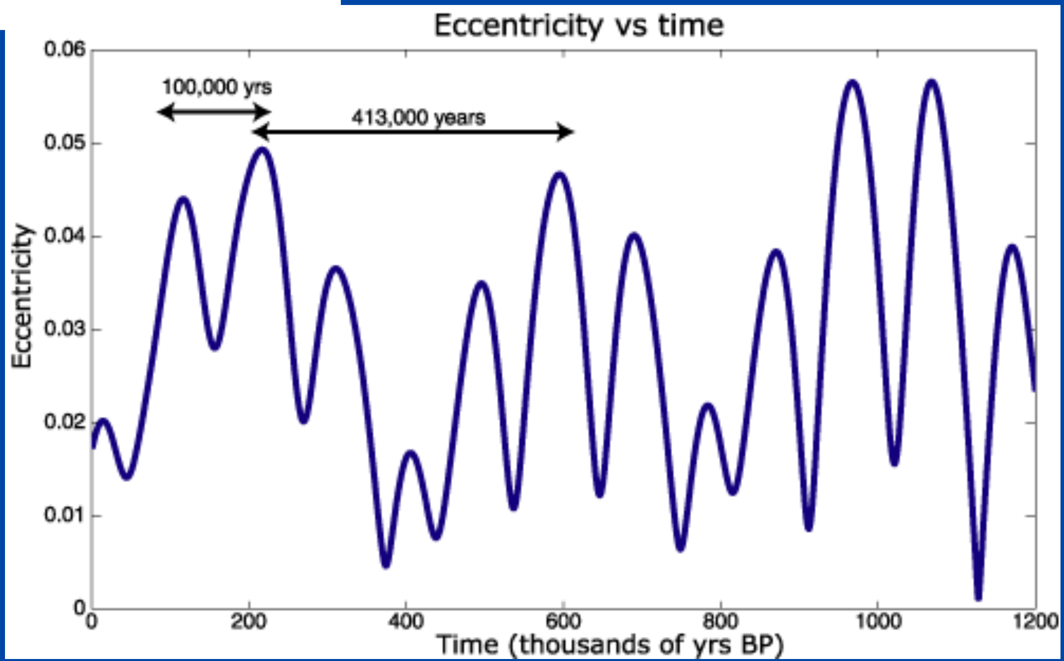
Orbital forcing: Milankovitch Theory

Eccentricity: 100,000 years





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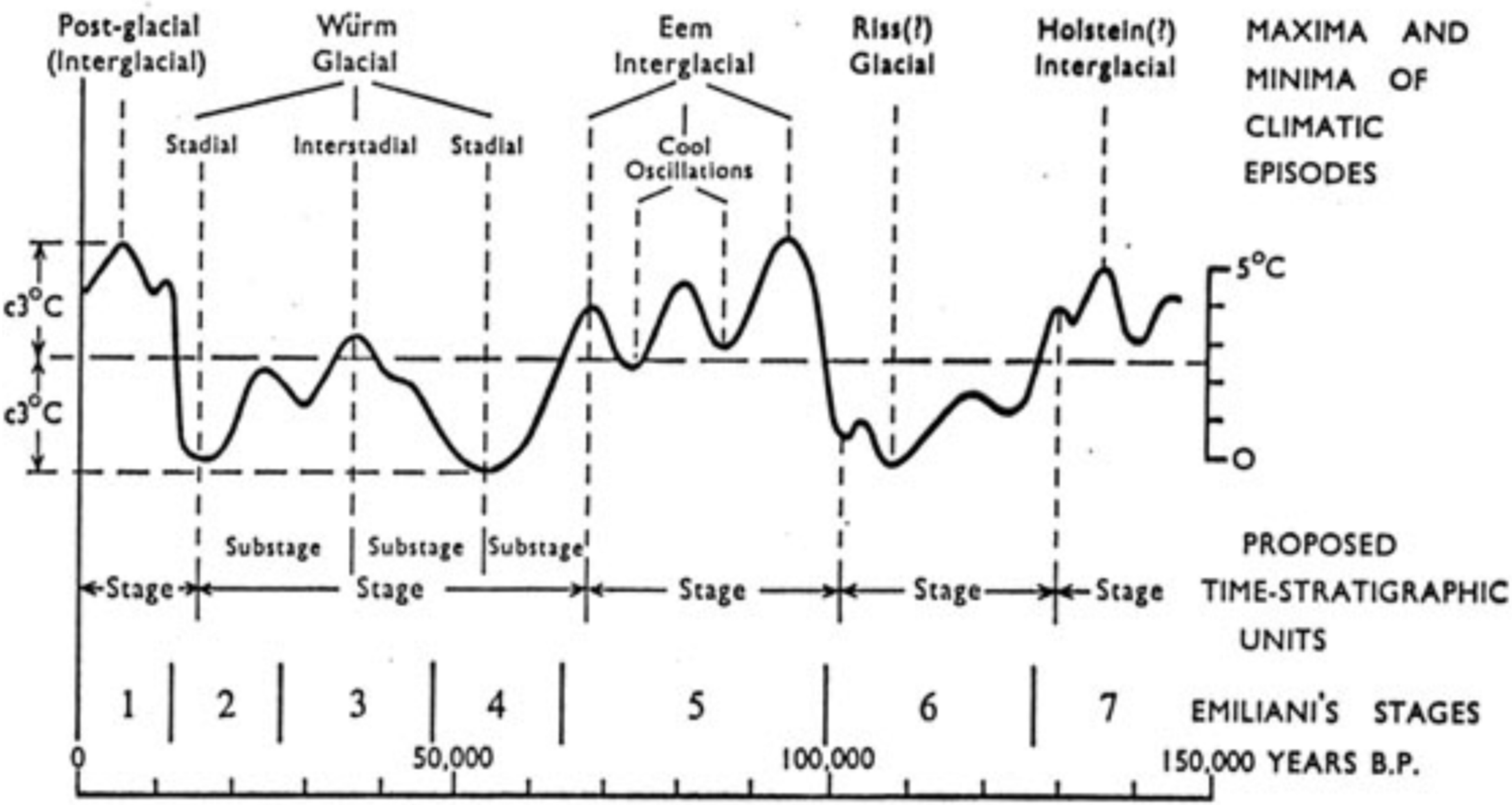

European Quaternary Glacial Stages

Millenial Scale Climate Change

- Last glacial maximum (LGM): ~21kya
- Bolling/Allerod warming-> Younger Dryas cooling:~13-11.9kya
- Heinrich events
- Dansgaard-Oeschger events

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Medieval Warming

- 10th century–14th century in Europe
 May recent finding in North America

- Coincided with a peak in solar activity

Sritrairat 20

Little Ice Age

- A period of cooling from approx. 14th–19th century, occurs after the medieval warming, though there seems to be little global agreement on the timing.
- Most evidence in Europe and north America
- Hypotheses of the cause include decreased sunspot activity (Maunder minimum) and increased volcanic activity, others claim it had to do with a decrease in population resulting from the black death and thus a decrease in agricultural activity

Time line

- 600-750 Ma: Snowball Earth (Neoproterozoic)
- 300 Ma-5Ma: Hot house world (Mesozoic/Cenozoic)
- 3 Myr-present: Orbital-scale variability: series of glaciation and retreat
- 20 Kyr: Last glacial maximum (LGM)
- ~13 Kyr:Bolling/Allerod warming
- ~12 Kyr: Younger Dryas (YD)
- Heinrich events and D-O cycles;
- 1000-1300 BP: Medieval Warm Period
- 1400-1800 BP: Little Ice Age

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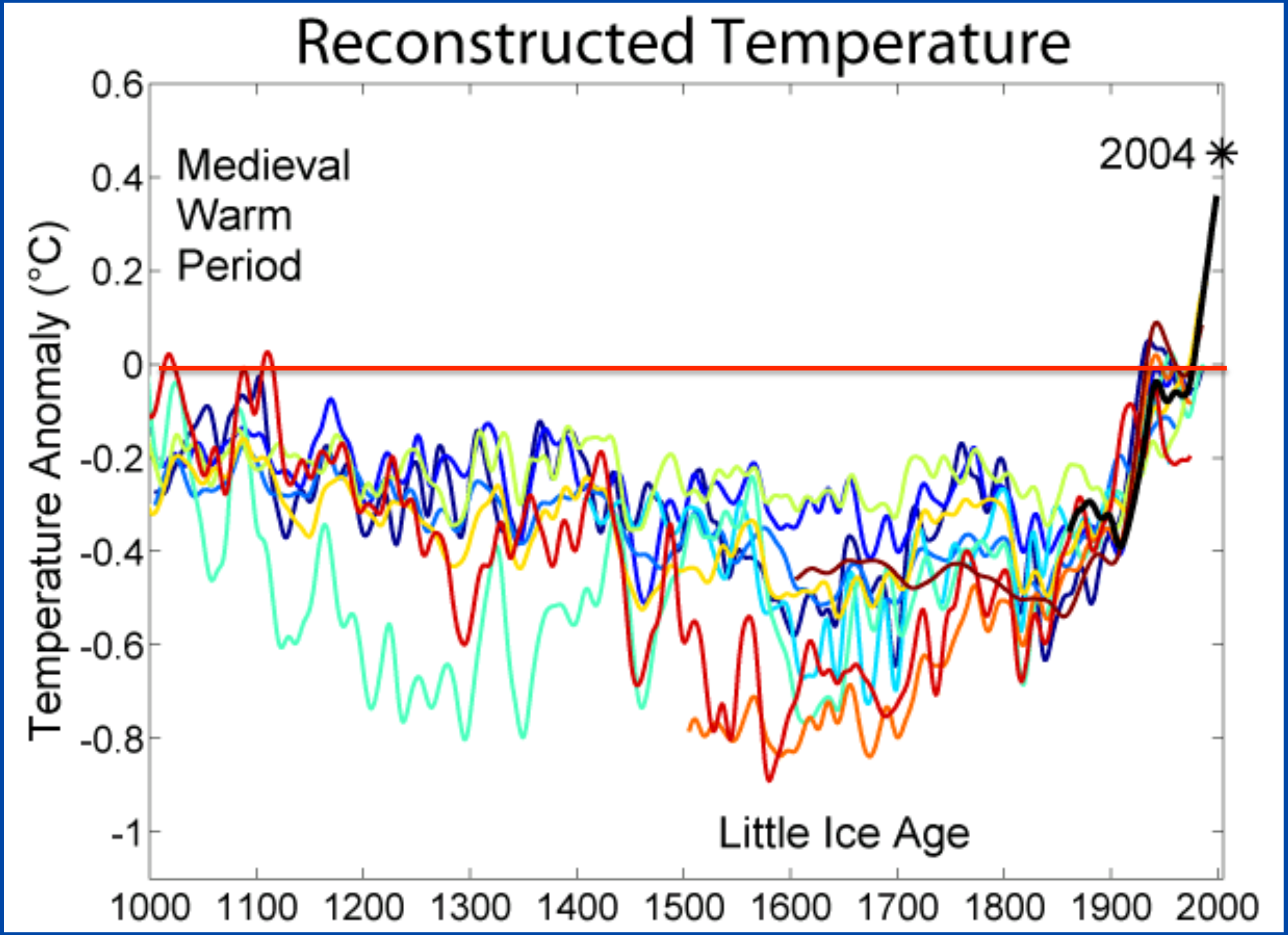
Global Warming?: The Hockey Stick



The infamous Mike Mann’ s“Hockey Stick” graph – The temperature is rising rapidly

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How to study paleoclimate?

Marine

- Ocean sediment cores (more regional)

Terrestrial (more local)

- Lakes and wetlands cores
- Tree ring/Coral (growth response)
- Leaf morphology
- Ice cores
- Speleothem
- Ice cores
- Sedimentary rocks/uplifted sediments

Modified after Sritrairat 2007

Proxies: plant and animal remains

- Pollens, forams
- Molecular techniques (transformation of molecules at a specific condition, or specific remains of group of living organism).i.e. alkenones, lignin
- Each species has a specific range of habitat (precip, T, soil type, nutrients, salinity)
- i.e. found foram in freshwater wetland cores: must have been saltier, Tropic pollen in the arctic = warmer

Proxies: Stable Isotopes

- If relative ratios of the selected pair changes systematically according to climatic parameters (T, precip, pH, etc)
- Mg/Ca: T
- $\delta^{13}C$: ocean circulation, productivity, C cycle
- $\delta^{18}O$:Temperature/Salinity/Sea level
  - More ice on land: ocean $\delta^{18}O$ becomes heavier

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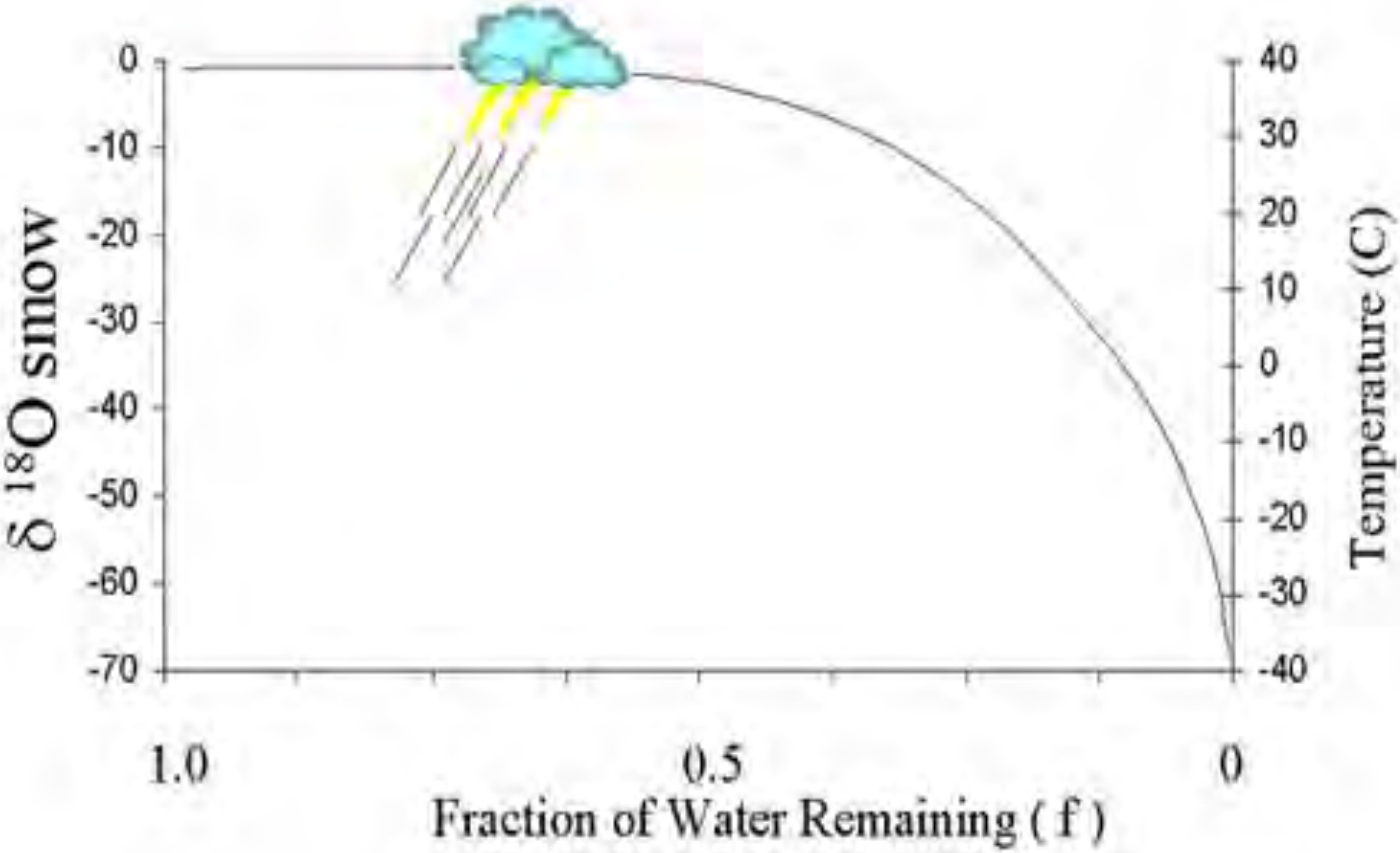
Rayleigh Distillation (Precipiation Fraction)



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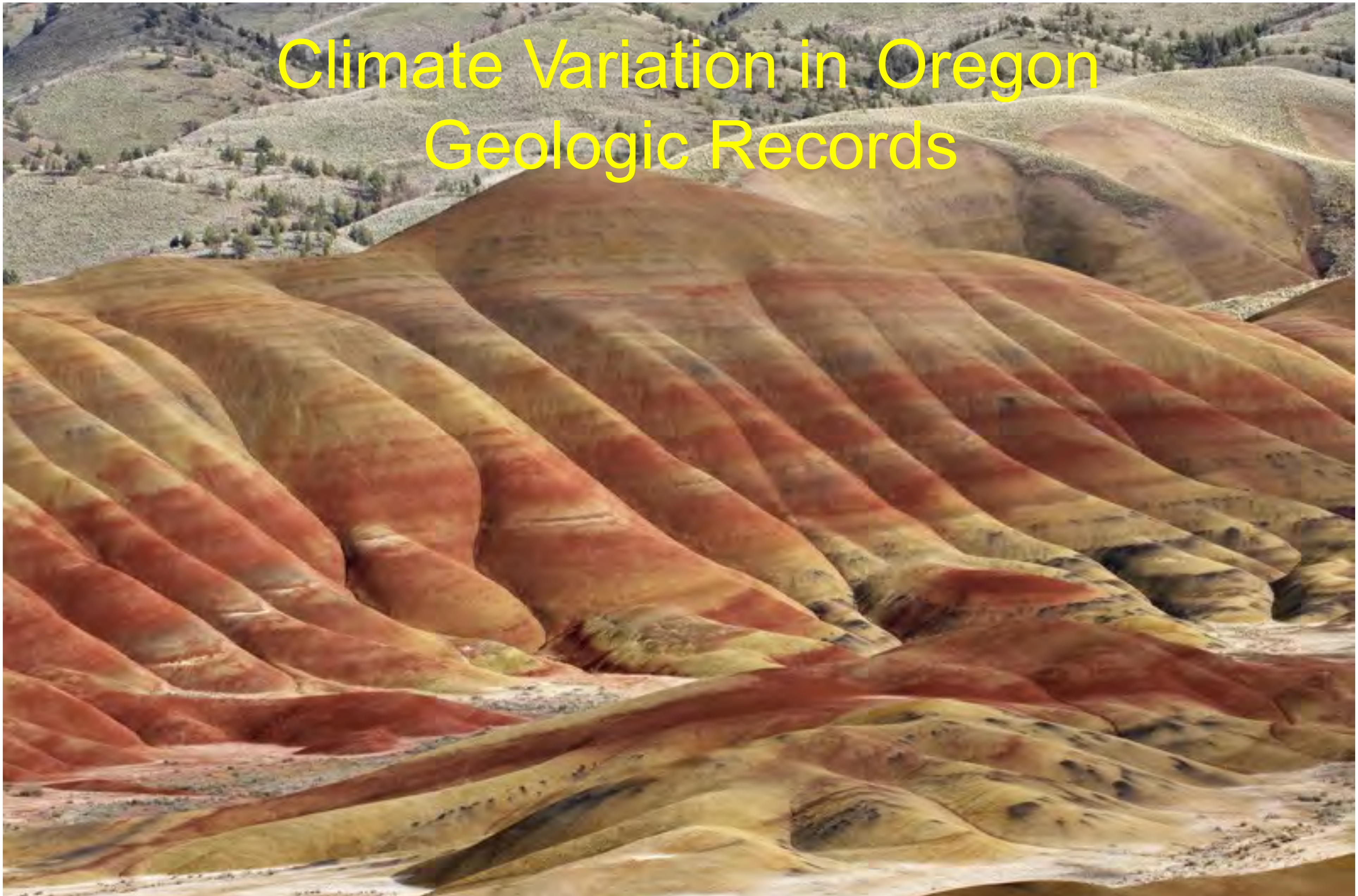
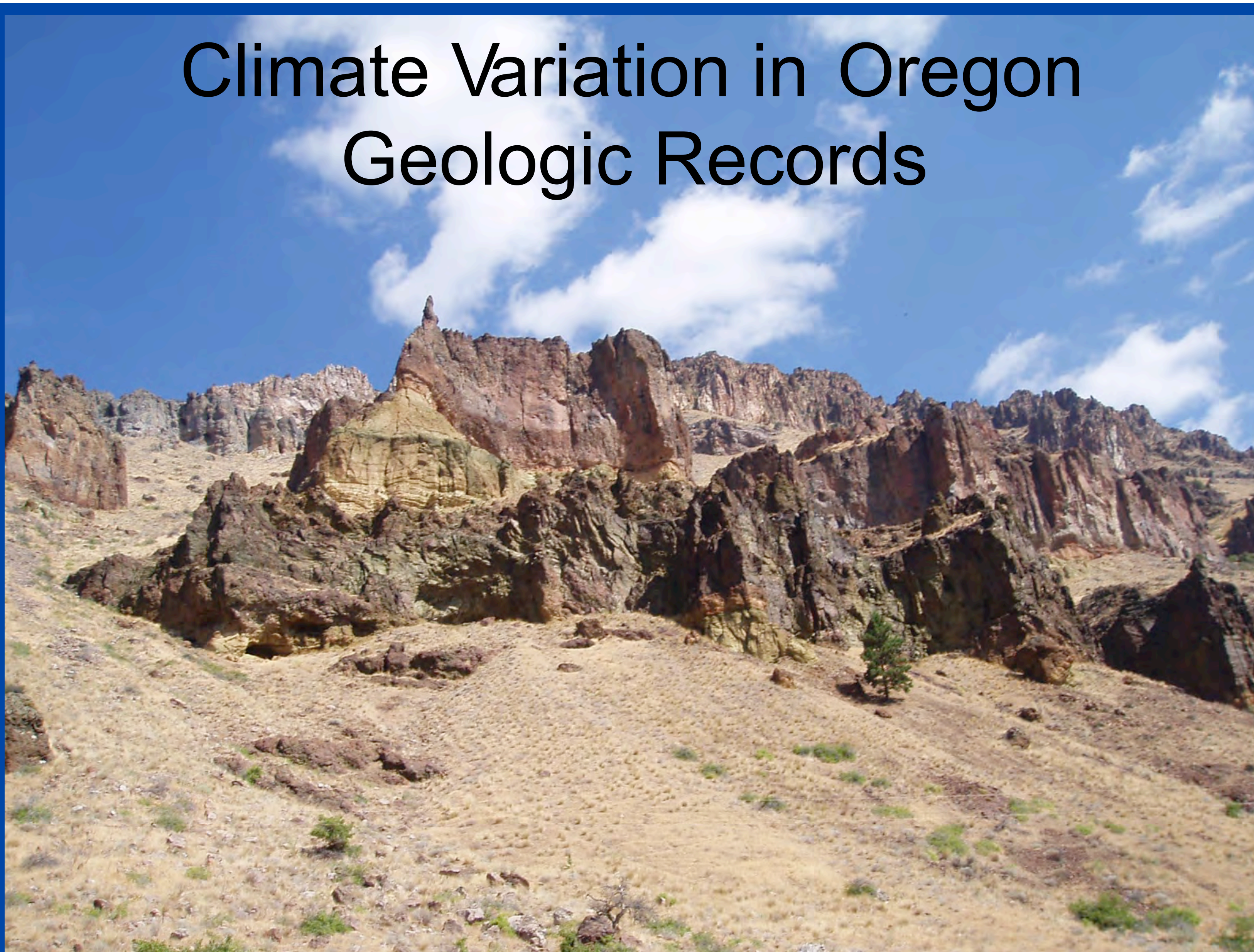
Climate Variation in Oregon Geologic Records



Painted Hills Unit, John Day Fossil Beds Nat Mon

http://www.botanicalgarden.ubc.ca/potd/2007/04/painted_hills_john_day_fossil_beds_national_monument.php

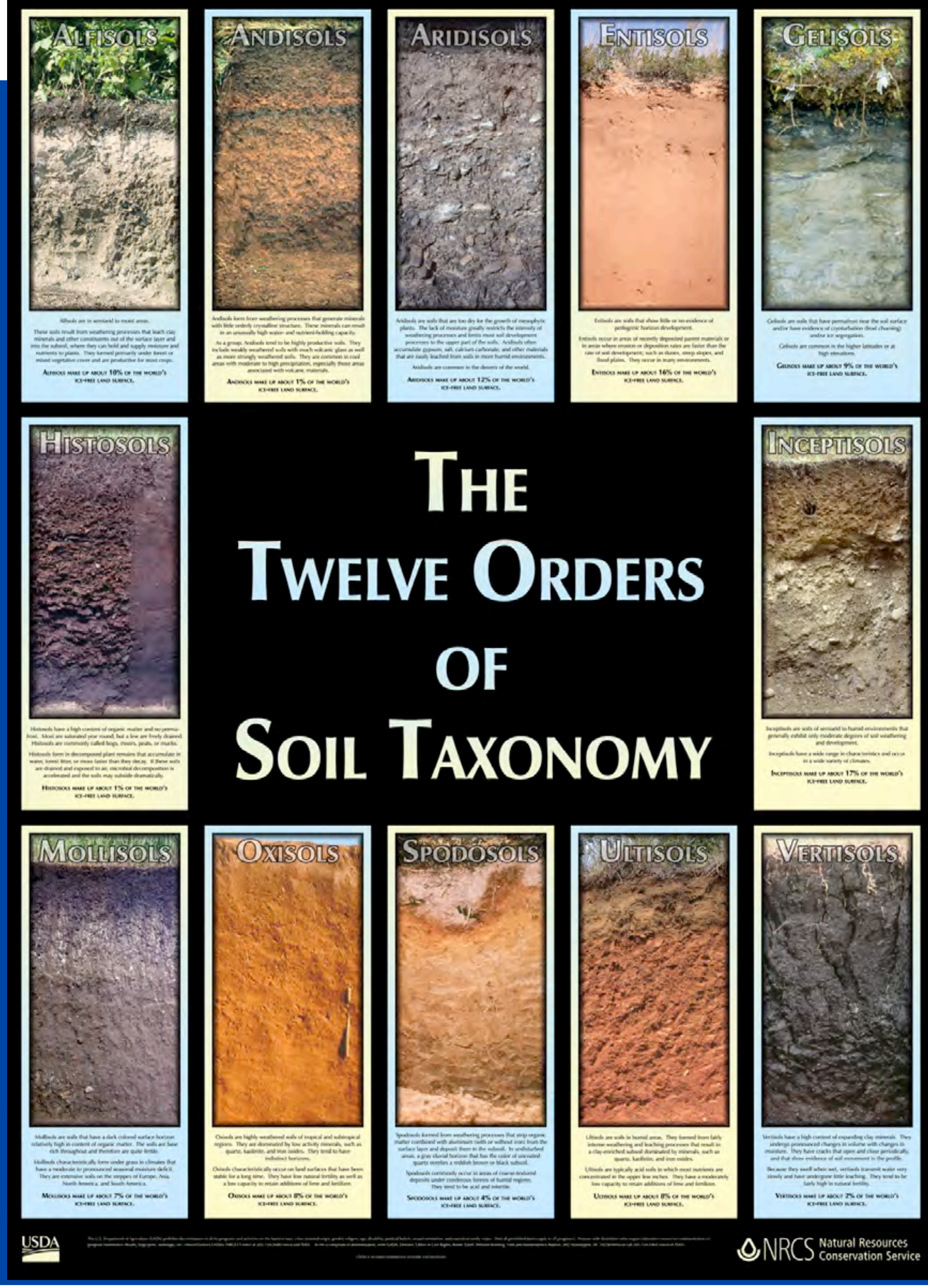
Climate Variation in Oregon
Geologic Records



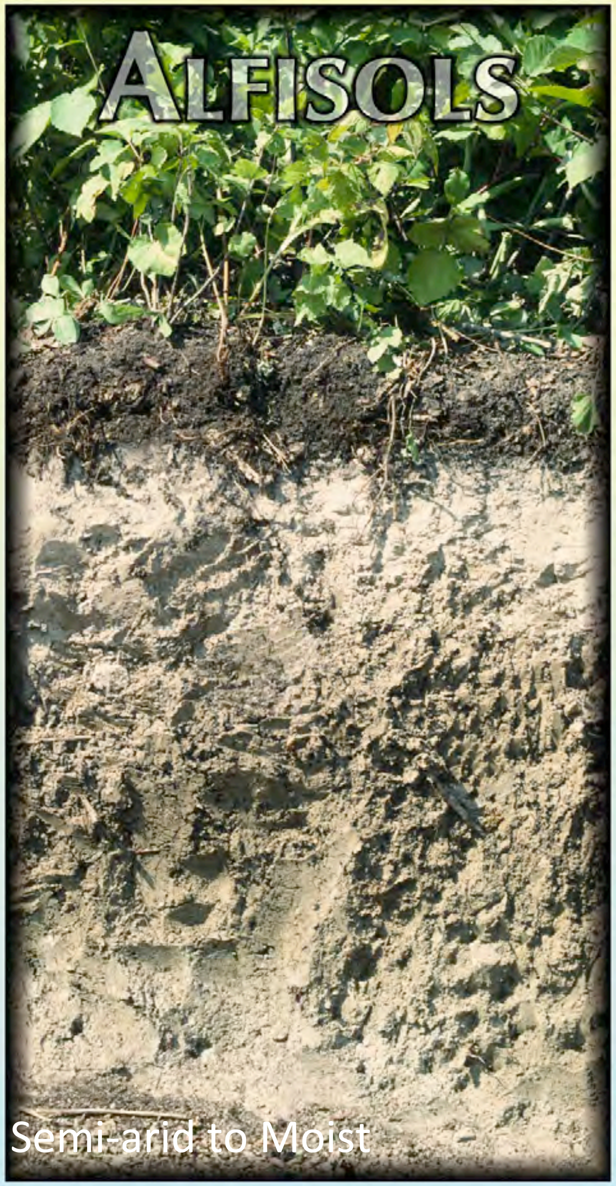
Clarno Formation above John Day River

http://www.botanicalgarden.ubc.ca/potd/2007/04/painted_hills_john_day_fossil_beds_national_monument.php

http://www.wou.edu/las/physci/taylor/eisi/photos_2007/deschutes_clarno2.jpg



http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_053588



Alfisols are in semiarid to moist areas.

These soils result from weathering processes that leach clay minerals and other constituents out of the surface layer and into the subsoil, where they can hold and supply moisture and nutrients to plants. They formed primarily under forest or mixed vegetative cover and are productive for most crops.

ALFISOLS MAKE UP ABOUT 10% OF THE WORLD'S ICE-FREE LAND SURFACE.

Andisols form from weathering processes that generate minerals with little orderly crystalline structure. These minerals can result in an unusually high water- and nutrient-holding capacity.

As a group, Andisols tend to be highly productive soils. They include weakly weathered soils with much volcanic glass as well as more strongly weathered soils. They are common in cool areas with moderate to high precipitation, especially those areas associated with volcanic materials.

ANDISOLS MAKE UP ABOUT 1% OF THE WORLD'S ICE-FREE LAND SURFACE.

Ultisols are soils in humid areas. They formed from fairly intense weathering and leaching processes that result in a clay-enriched subsoil dominated by minerals, such as quartz, kaolinite, and iron oxides.

Ultisols are typically acid soils in which most nutrients are concentrated in the upper few inches. They have a moderately low capacity to retain additions of lime and fertilizer.

ULTISOLS MAKE UP ABOUT 8% OF THE WORLD'S ICE-FREE LAND SURFACE.

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_053588

Entisols are soils that show little or no evidence of pedogenic horizon development.

Entisols occur in areas of recently deposited parent materials or in areas where erosion or deposition rates are faster than the rate of soil development; such as dunes, steep slopes, and flood plains. They occur in many environments.

ENTISOLS MAKE UP ABOUT 16% OF THE WORLD'S ICE-FREE LAND SURFACE.

Inceptisols are soils of semiarid to humid environments that generally exhibit only moderate degrees of soil weathering and development.

Inceptisols have a wide range in characteristics and occur in a wide variety of climates.

INCEPTISOLS MAKE UP ABOUT 17% OF THE WORLD'S ICE-FREE LAND SURFACE.

Aridisols are soils that are too dry for the growth of mesophytic plants. The lack of moisture greatly restricts the intensity of weathering processes and limits most soil development processes to the upper part of the soils. Aridisols often accumulate gypsum, salt, calcium carbonate, and other materials that are easily leached from soils in more humid environments.

Aridisols are common in the deserts of the world.

ARIDISOLS MAKE UP ABOUT 12% OF THE WORLD'S ICE-FREE LAND SURFACE.

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_053588

Tetallack 2009 Cenozoic cooling and grassland expansion in Oregon and Washington *PaleoBios*

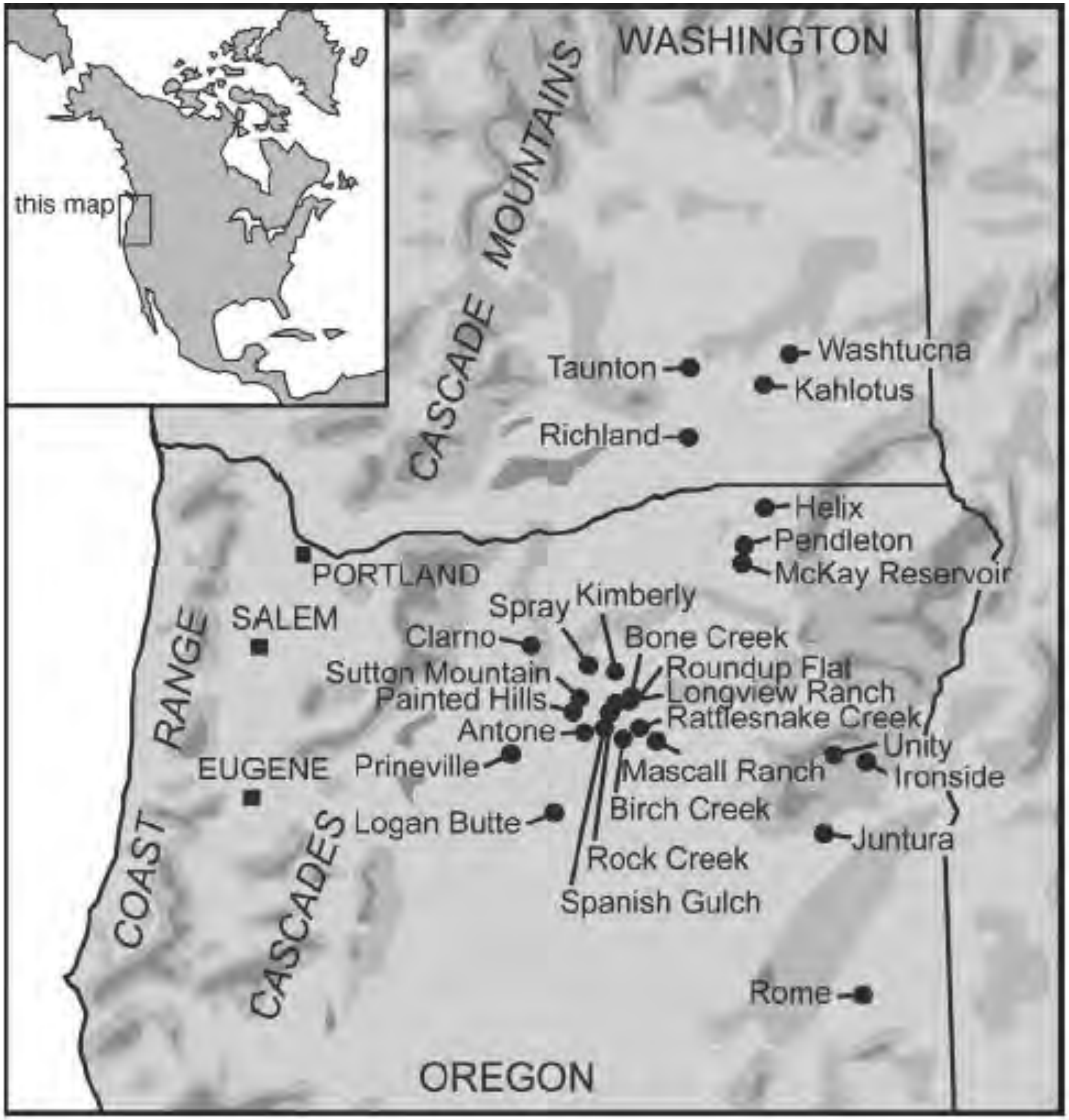


Figure 1. Localities of paleosols examined in Oregon and Washington.

Retallack 2008

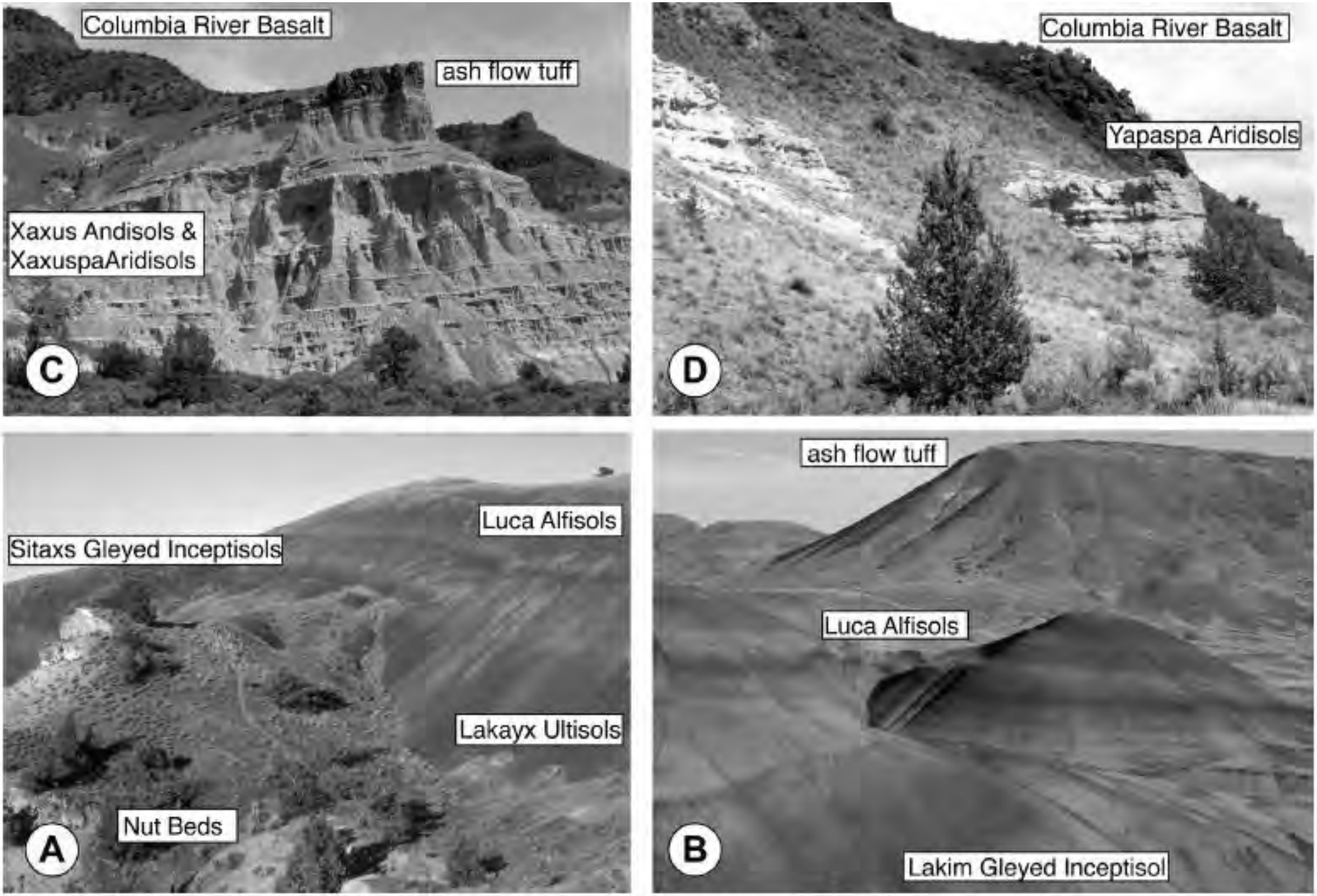
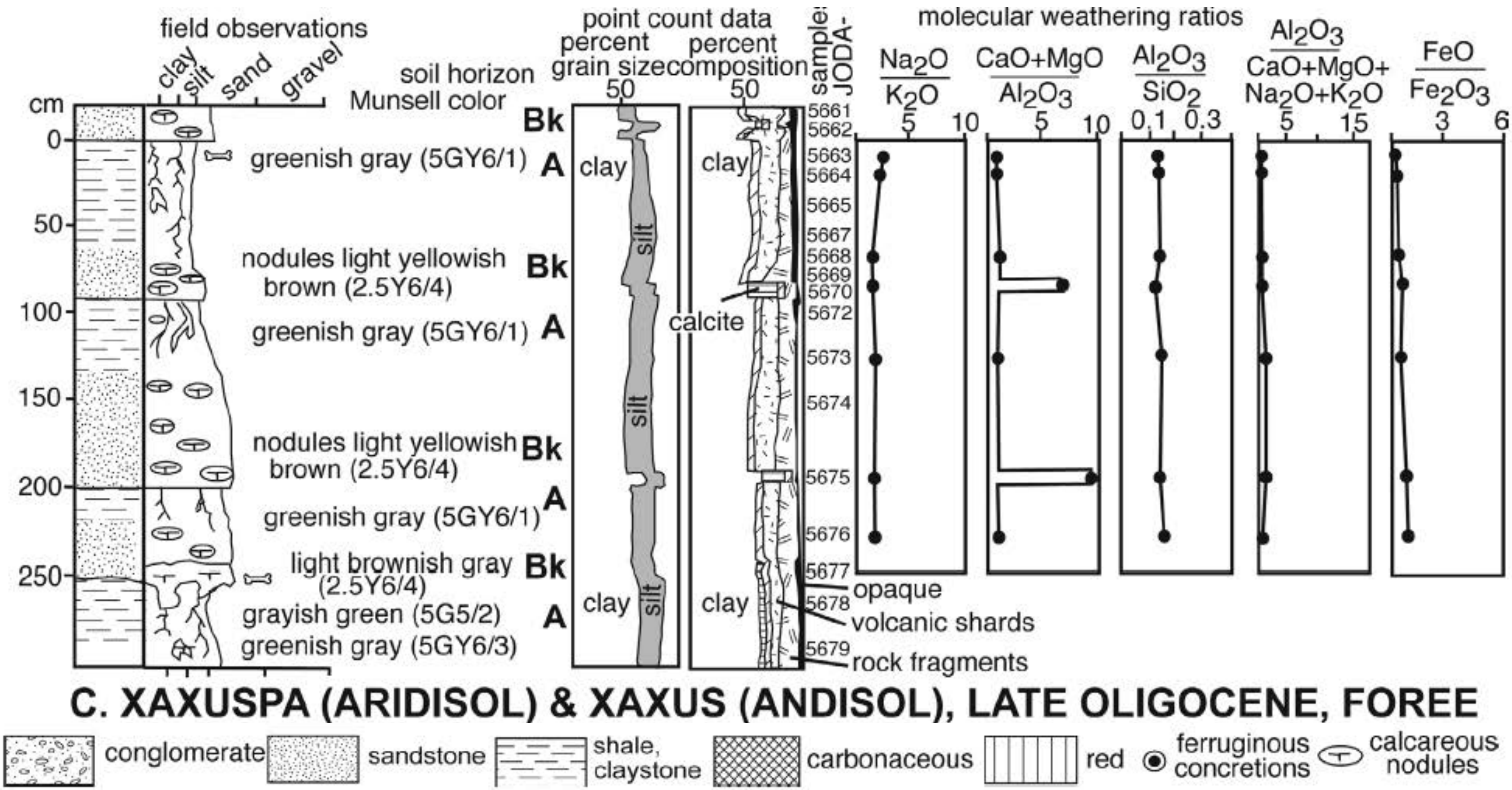
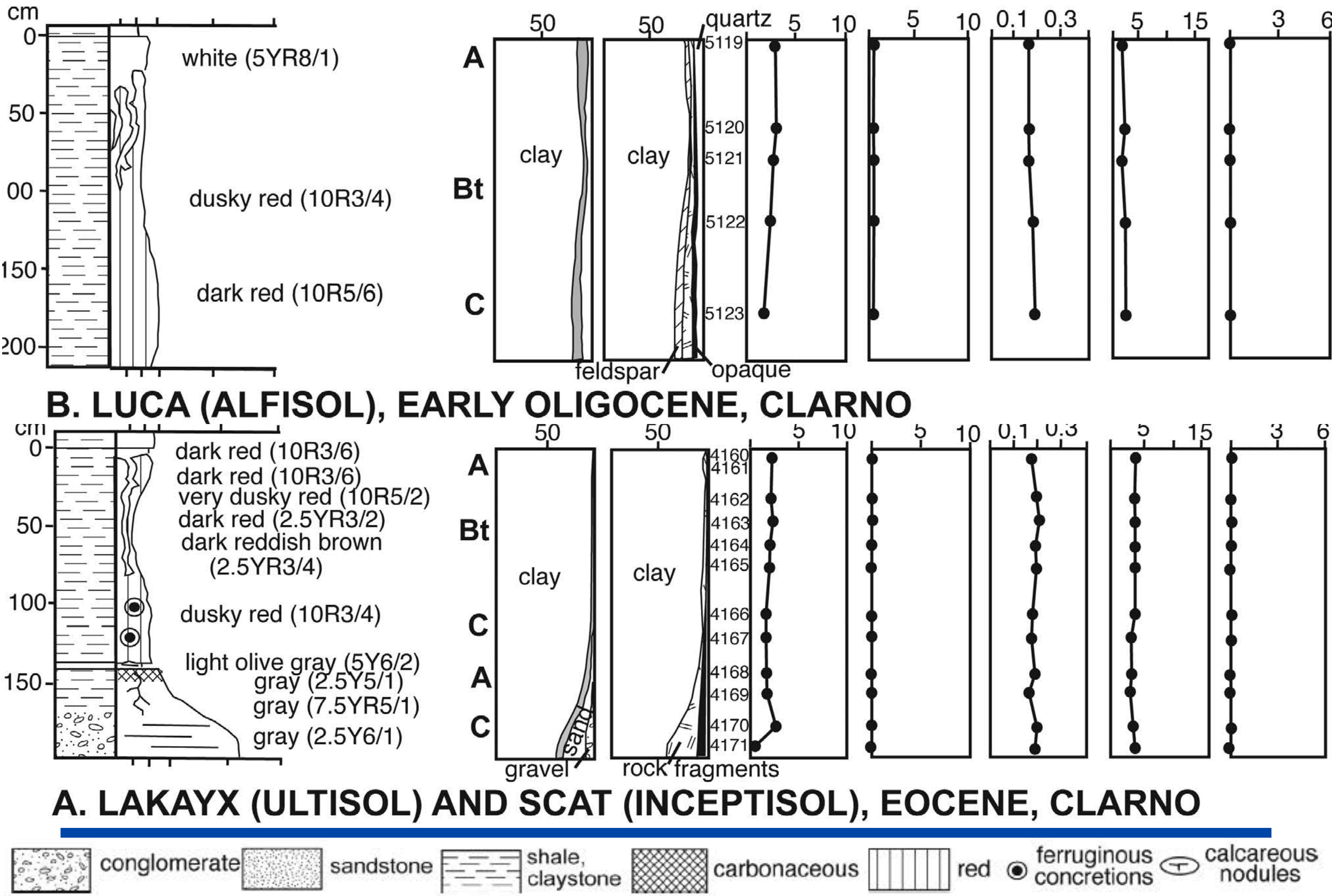


Figure 2. Field photographs of selected paleosols: **A.** Ultisols and Alfisols above the Nut Beds near Clarno. **B.** Alfisols and Gleyed Inceptisols in the central Painted Hills. **C.** Aridisols and Andisols at Foree north of Kimberly. **D.** Caprock Aridisols south of Kimberly.

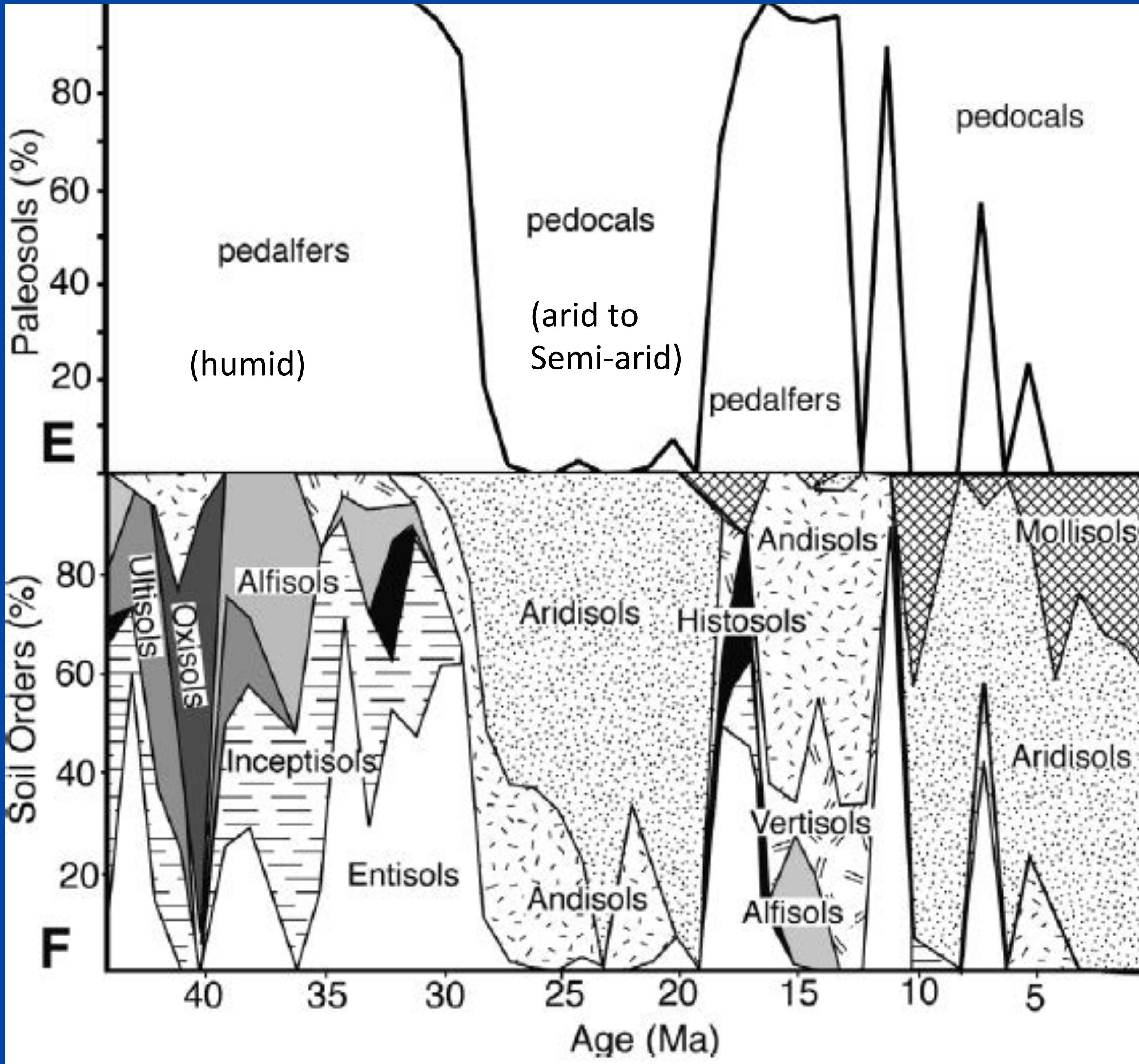
Retallack 2008



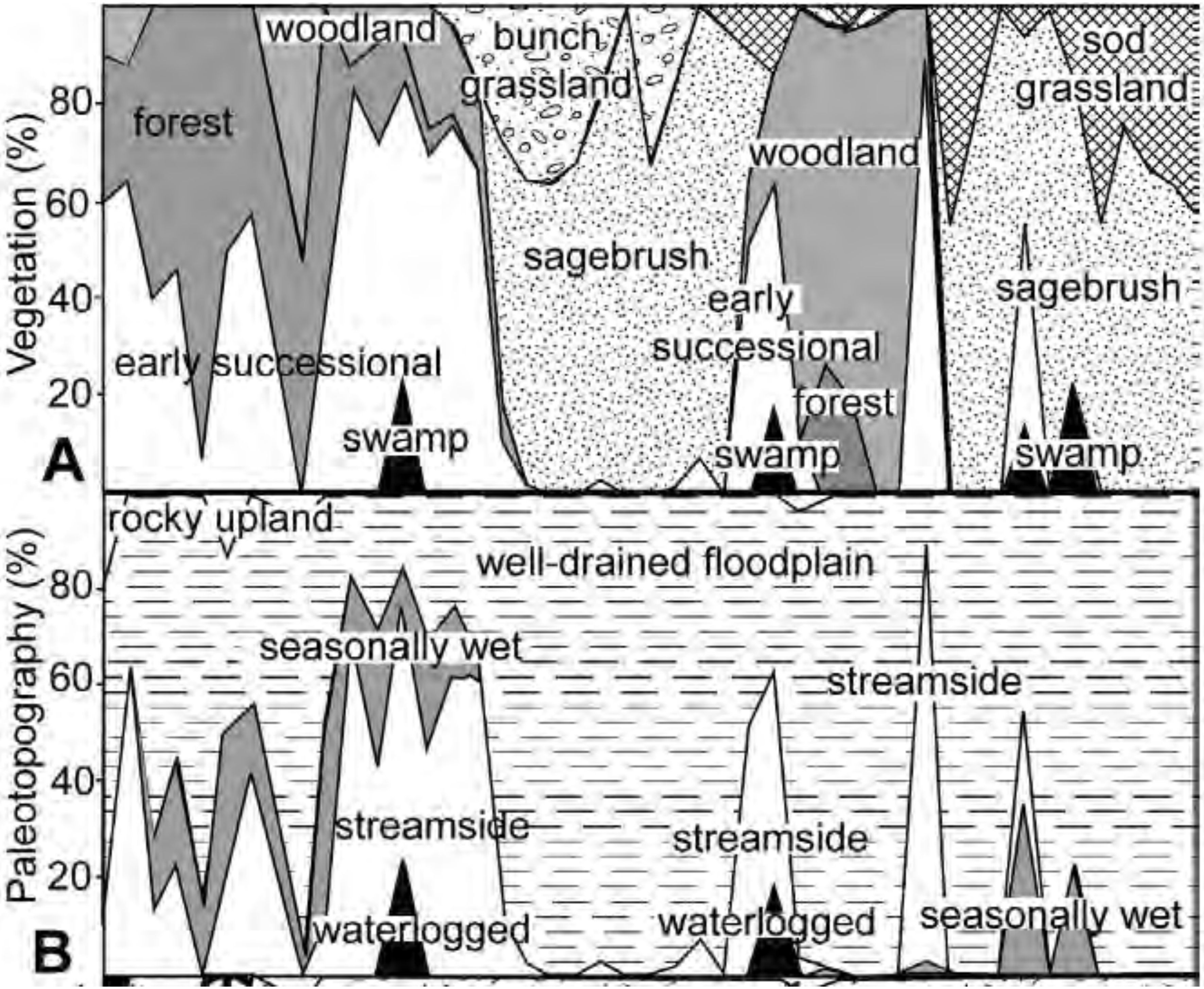
Retallack 2008



Retallack 2008



Retallack 2008



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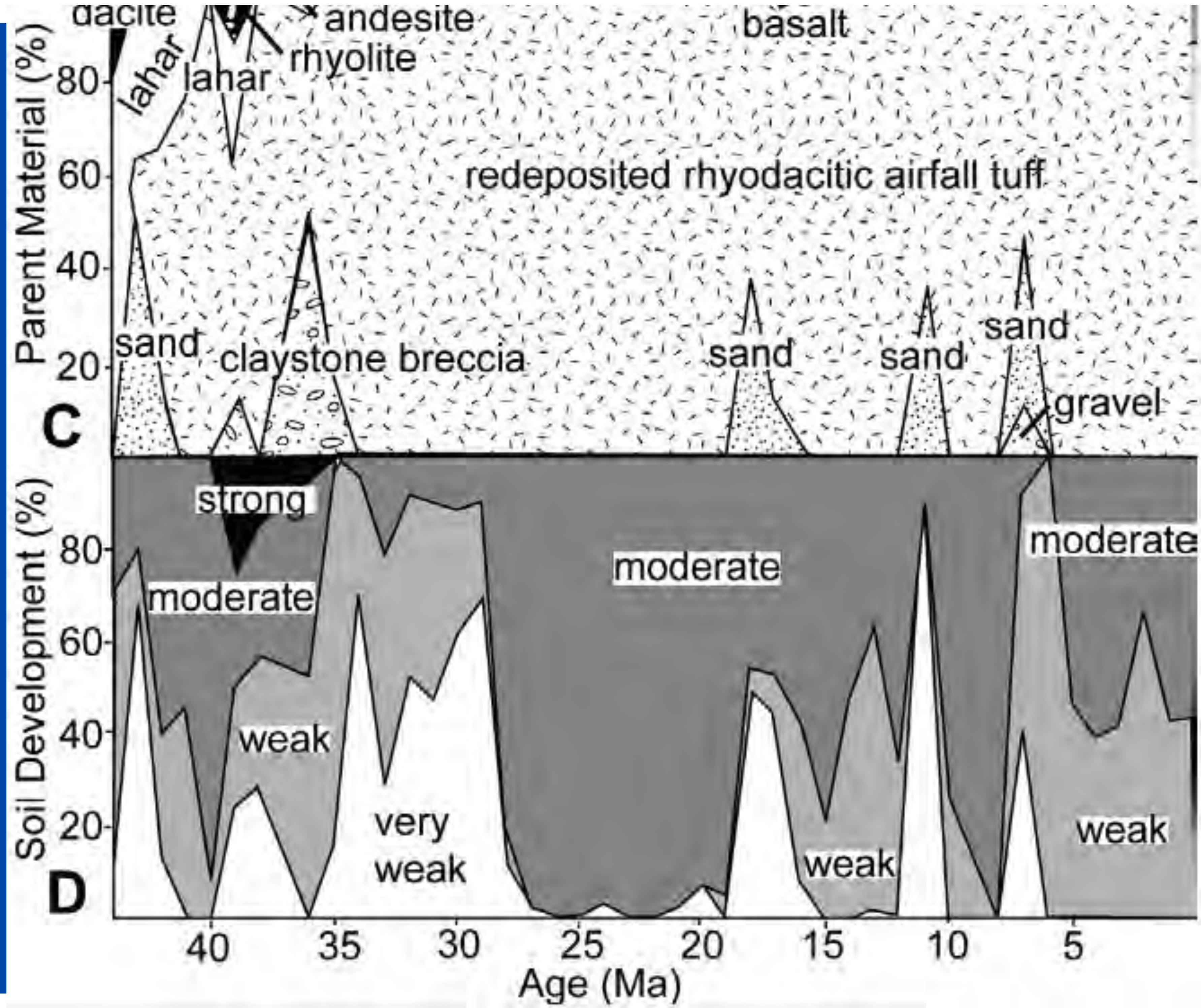

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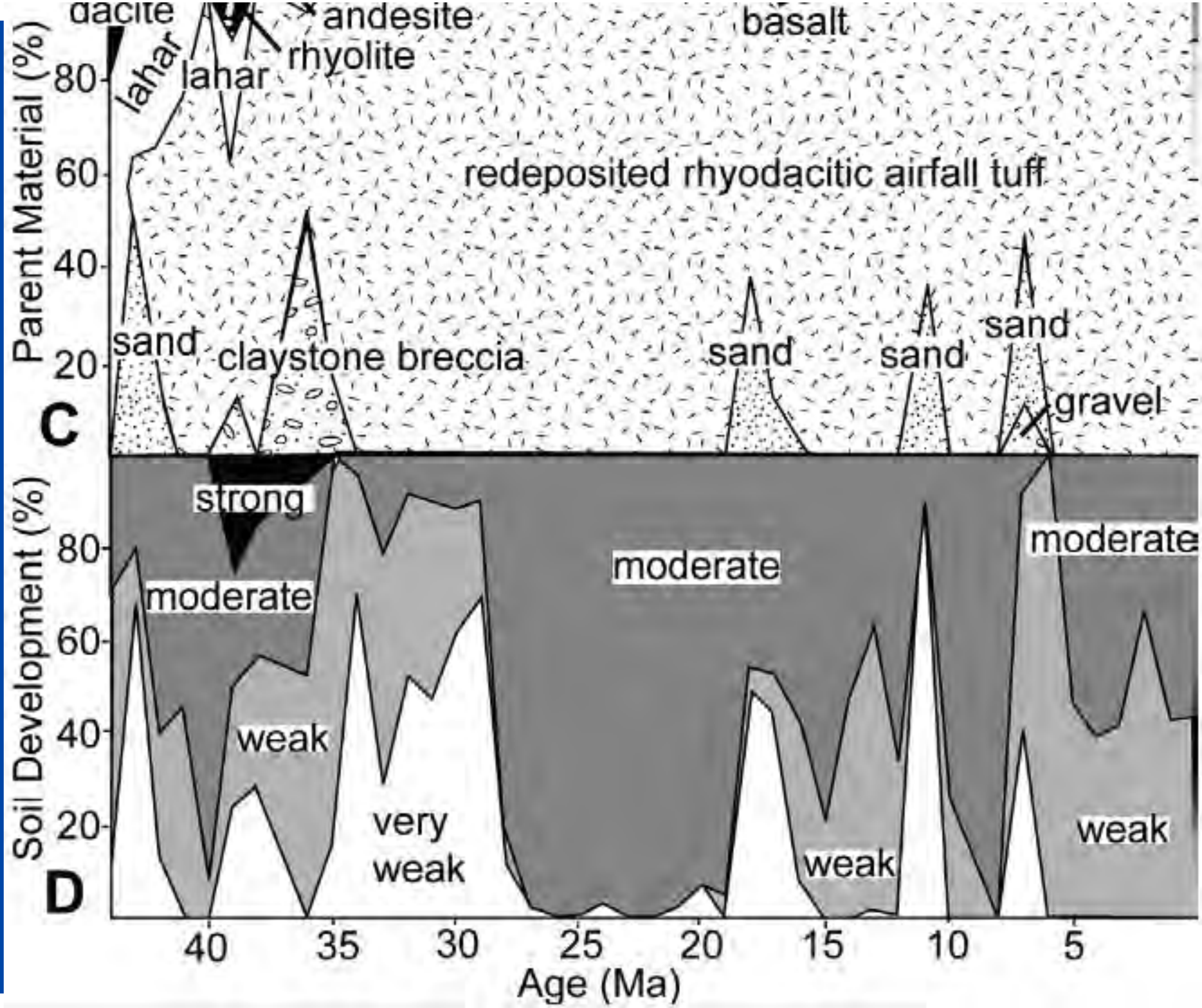


Retallack 2008

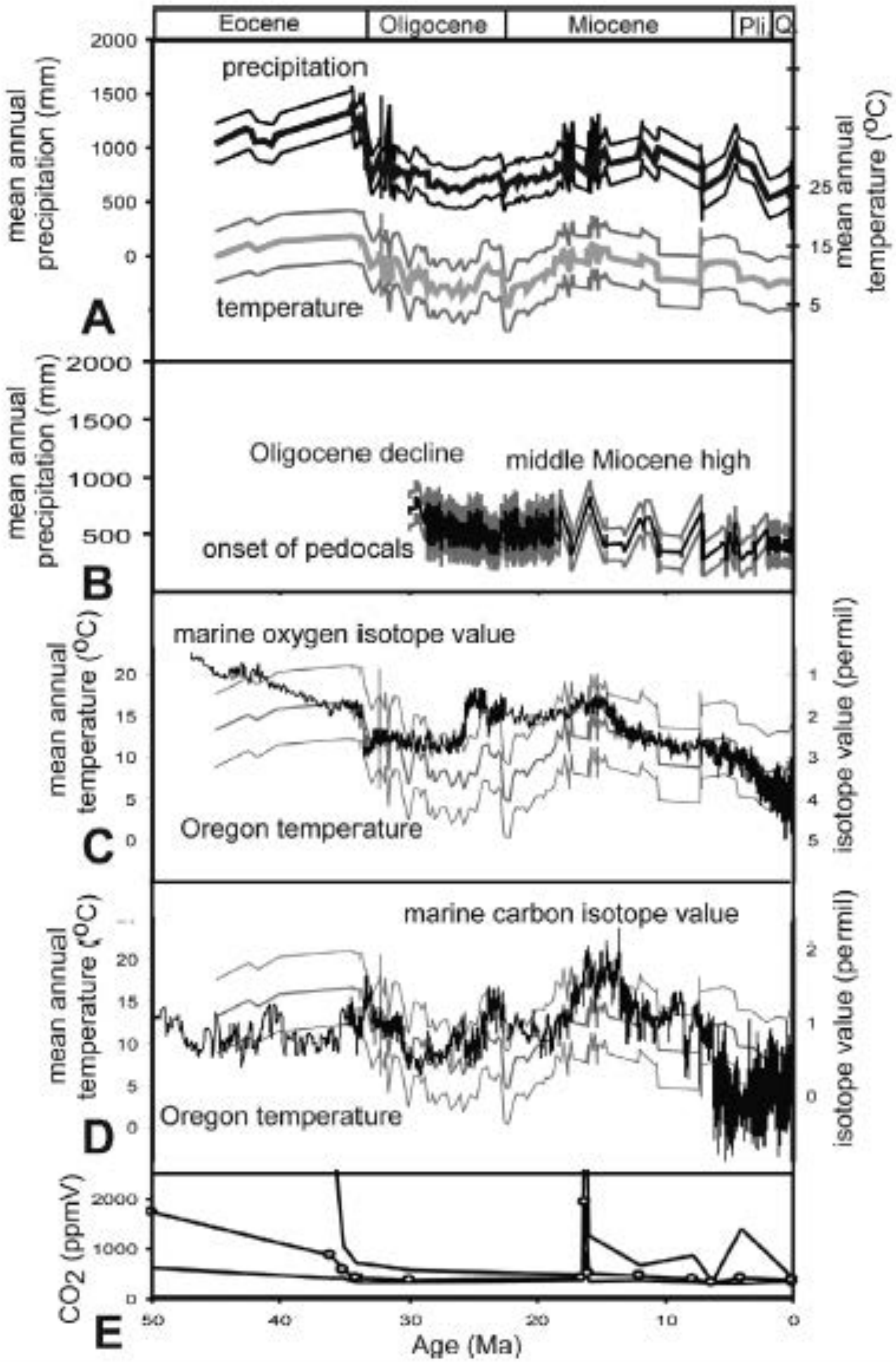
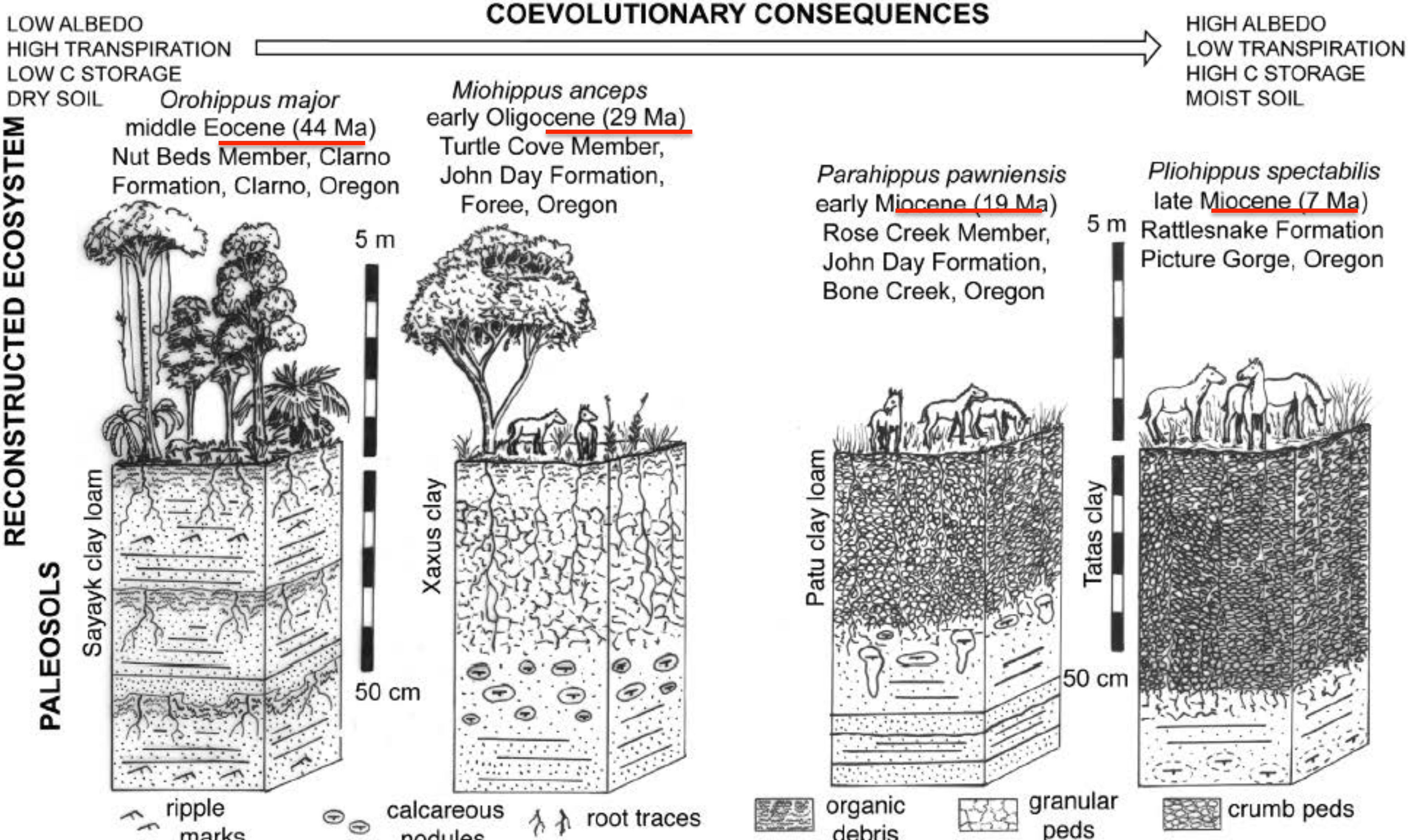


Figure 8. Cenozoic variation in mean annual precipitation (**A**) and mean annual temperature (**B**) inferred from paleosol chemistry (**A, B**) and depth to calcic horizons (**B**), compared with oxygen and carbon isotopic composition of marine foraminifera (**C–D**), and CO_2 levels inferred from stomatal index (**E**). Data of **A** and **B** from Retallack (2004a,b) and Retallack et al. (2000), with flanking curves one standard error from the transfer function; data of **C** and **D** from Zachos et al. (2001); data of **E** from Retallack (2001b, 2002) with flanking curves one standard deviation of the stomatal index measurement, using transfer function of Wynn (2003).

Retallack 2008



Retallack 2008

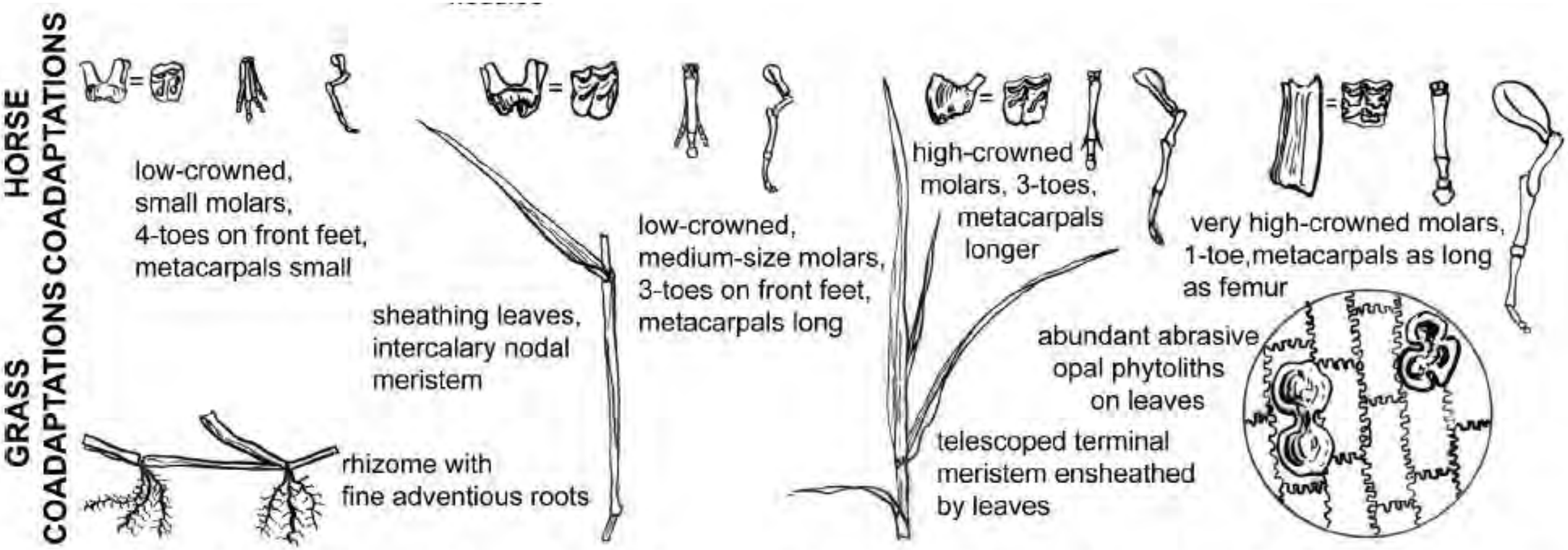


Figure 10. Coevolution of grasses and grazers. Although only examples of paleosols and fossil horses from Oregon are shown, comparable evolutionary change is known from all continents except Australia and Antarctica, and may have had global change consequences.

Retallack 2008

Painted Hills Unit, John Day Fossil Beds National Monument

http://www.botanicalgarden.ubc.ca/potd/2007/04/painted_hills_john_day_fossil_beds_national_monument.php

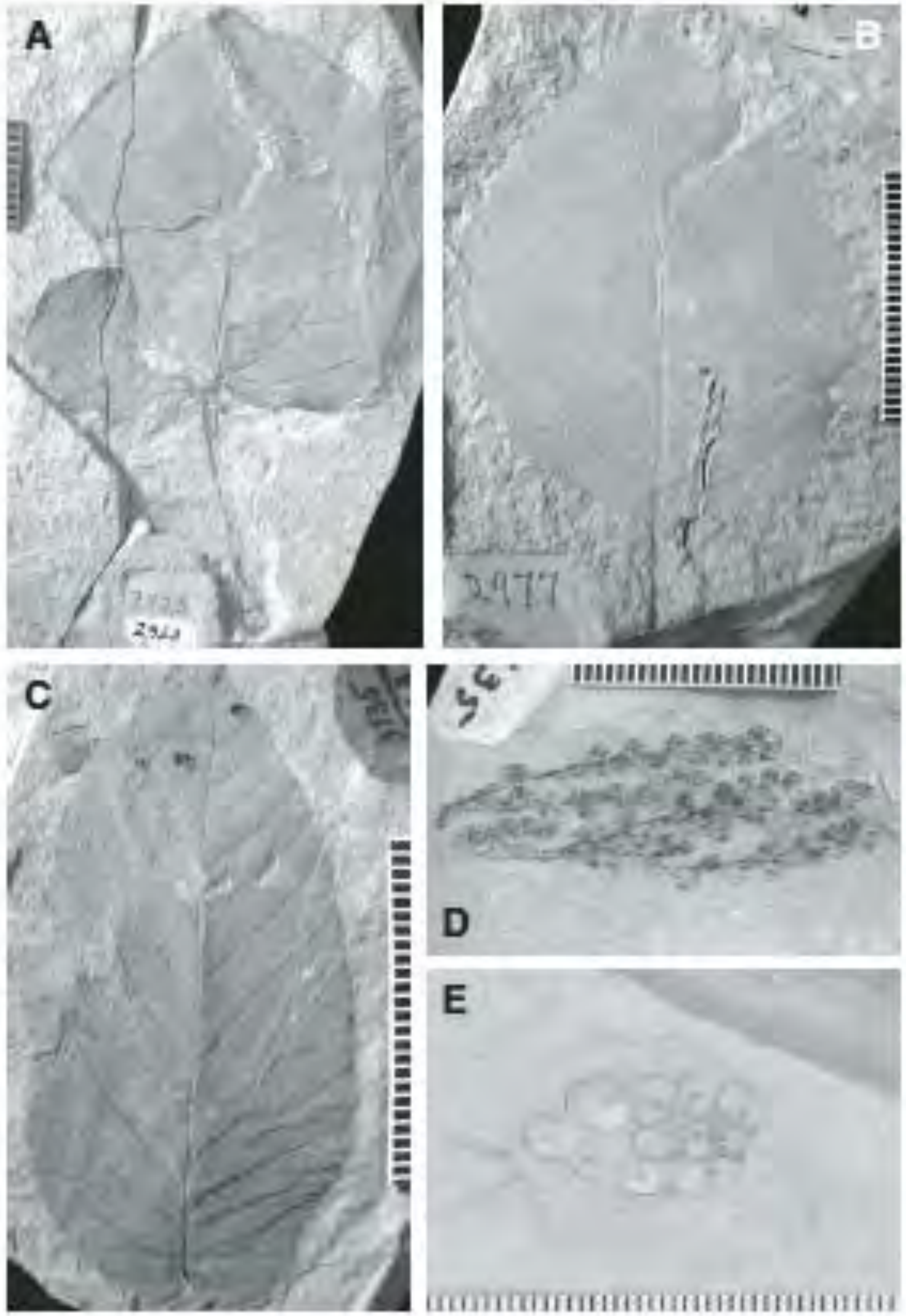


Figure 17. Leaves (A–C) and reproductive structures (D–E) found in the Mascall flora (Chaney and Axelrod, 1959). (A) *Populus lindgreni* (hypotype, UCMP 2923). (B) *Betula thor* (hypotype, UCMP 2977). (C) *Ostrya oregoniana* (hypotype, UCMP 2984). (D) *Taxodium dubium*, shoot with staminate cones (hypotype, UCMP 2905). (E) Nymphaceae fruit. Scale in mm. Specimens in A–D photographed by D.M. Erwin, courtesy of the UCMP.

Dilhoff et al 2004

2:30

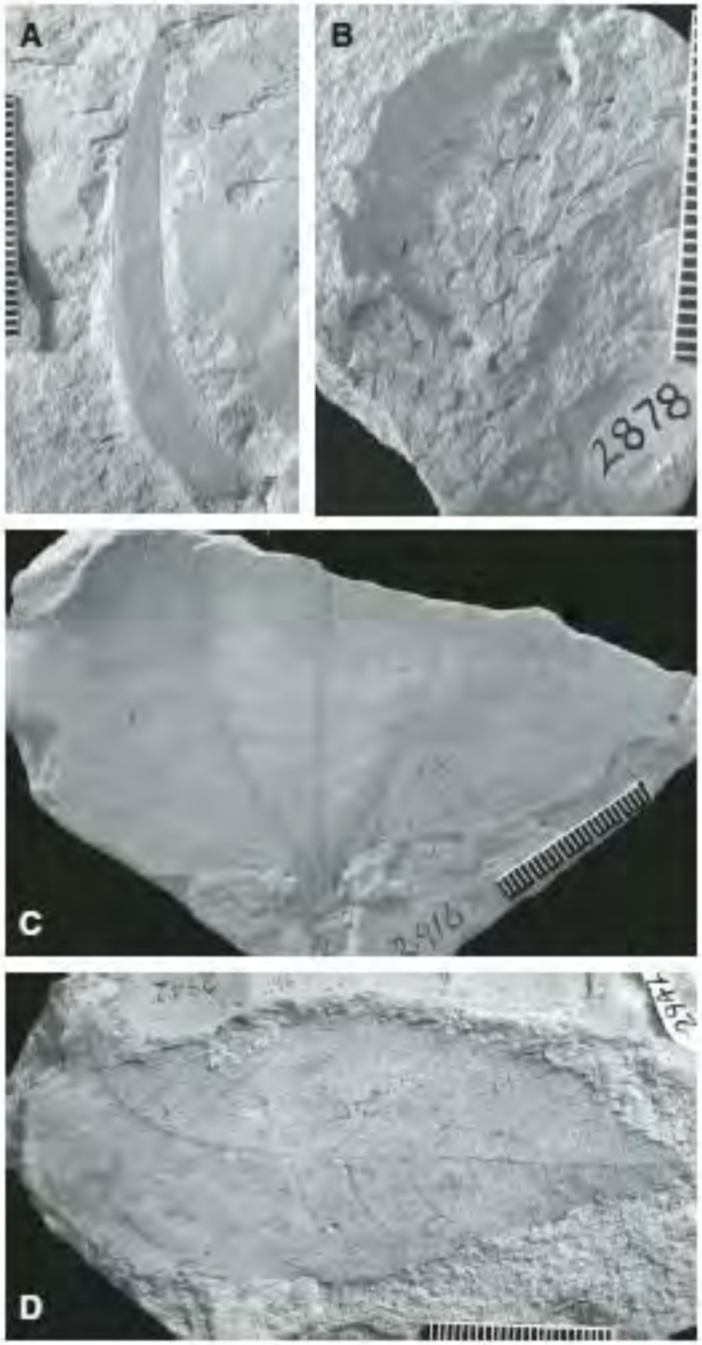


Figure 16. Some common and rare leaves/foliage types found in the Mascall flora (Chaney and Axelrod, 1959). (A) *Cephalotaxus californica* (hypotype, UCMP 2824). (B) *Thuja dimorpha* (hypotype, UCMP 2878). (C) *Smilax magna* (hypotype, UCMP 2916). (D) *Carya bendirei* (hypotype, UCMP 2942). Scale in mm. Specimens photographed by D.M. Erwin, courtesy of the UCMP.

Dilhoff et al 2004

Locality	Age (Ma)	MAT (°C)	MAT Error(°C)	# Dicot Leaves
West Branch Creek	45	13.99	2.35	41
White Cliffs	44.5	14.29	1.94	61
Clarno Nut Beds	44	17.05	1.84	69
John Day Gulch	40	10.32	2.20	40
Kings Gap	39	15.50	3.18	19
White Cap Knoll	39	9.09	3.07	19
Sumner Spring	38	7.56	2.86	19
Slanting Leaf Beds	33.62	8.18	2.31	31
Nichols Spring	33	6.60	3.26	11
Canal Flora	33	6.00	3.55	10
Cove Creek	33	9.40	2.40	26
Lost Creek	33	10.62	2.83	18
Crooked River	33	8.48	1.81	41
Painted Hills	32.7	7.87	2.14	37
Fossil High School	32.58	11.85	1.93	53

Dilhoff et al 2004

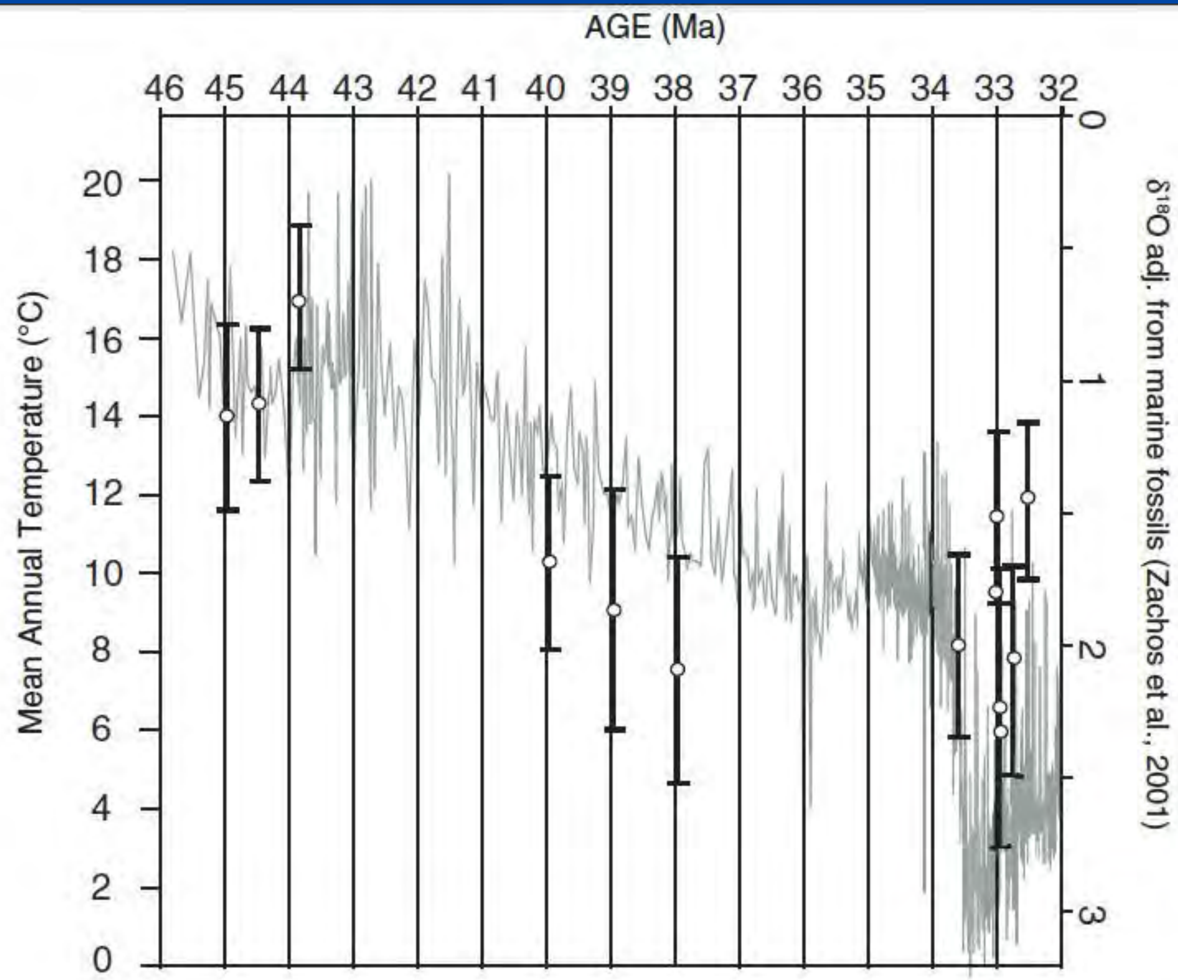
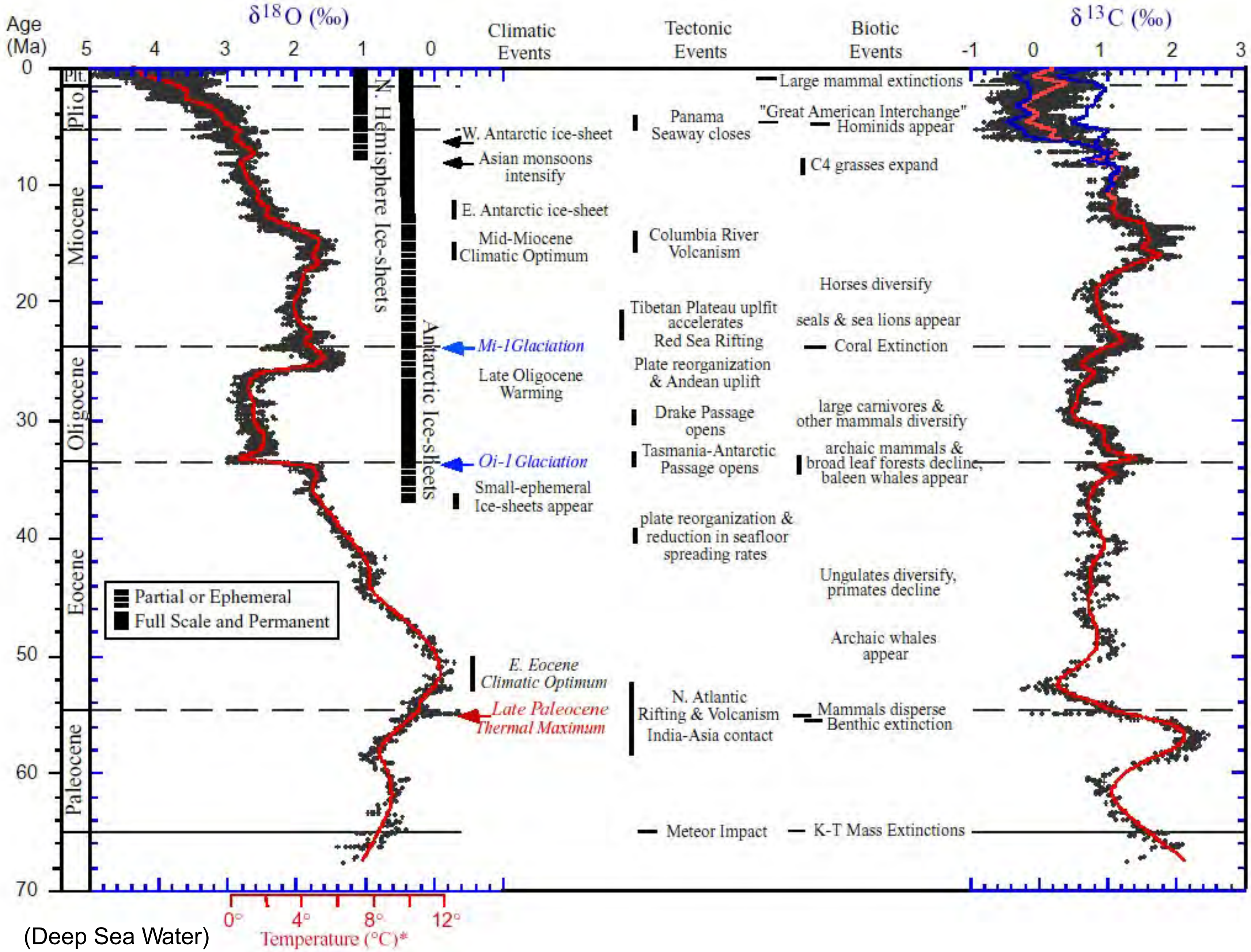


Figure 4. Comparison of the Cenozoic marine $\delta^{18}O$ isotopic record (Zachos et al. 2001) and changes in mean annual temperature (MAT) established from CLAMP (Climate-Leaf Analysis Multivariate Program) and leaf margin analyses of paleofloras from the John Day Basin. MAT estimates from Manchester (2000), Meyer and Manchester (1997), and Smith et al. (1998).

Dilhoff et al 2004



https://pangea.stanford.edu/research/Oceans/GES206/readings/Zachos2001.pdf

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