

Geologic Evaluation of North America

With a Focus on the US National Parks

with Nicole Myers

Week 6: Recent Landscape Deformation

<https://www.appreciatingearth.com/olli>



Video link: https://www.youtube.com/watch?v=xaj_J_3YJMc

Field Stations

The interactive map below provides links to campus biological field stations and marine laboratories.

← Sonoma State Laboratories Map

name
Sonoma State

description
Fairfield Osborn Preserve
<https://cei.sonoma.edu/preserves/osborn>

Galbreath Preserve
<https://cei.sonoma.edu/preserves/galbreath>

Los Guillicos
<https://cei.sonoma.edu/preserves/losguillicos>

National Park Service

“conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”

[National Park Service Organic Act of 1916]

Sonoma Co: 22% of lands conserved, inc. SSU’s Field Stations:

- Galbreath Wildlands Preserve
 - Fairfield Osborn Preserve
 - Los Guillicos Preserve
 - + Campus Nature Corridor
- Supporting the National Parks
- NP Conservation Association (NPCA)
 - National Park Foundation (NPF)
- Support other parks with -membership -donations -volunteerism

30x30 CALIFORNIA Conserved Areas

Overview Terrestrial Detailed Marine Detailed Help

Terrestrial Conservation Areas | Acres Conserved

26.5M Acres
out of 101.6M Acres (Total terrestrial area of CA)

26.10% of California

Marine Conservation Areas | Acres Conserved

737.6k Acres
out of 3.4M Acres (Total marine area of CA)

21.91% of California

Conservation Areas of California

Galbreath Wildlands Preserve

GAP 1	GAP 2
0%	98.02%
GAP 3	GAP 4
0%	1.98%

Agency Name: California State University Sonoma
Agency Type: State
Access Type: Restricted Access
Acres: 3728.00
Management Stack: CPAD/KCED

Fairfield Osborn CE

GAP 1	GAP 2
0%	100%
GAP 3	GAP 4
0%	0%

Agency Name: The Nature Conservancy
Agency Type: Non Profit
Access Type: Restricted Access
Acres: 184.85
Management Stack: Conservation Easement: Fairfield Osborn Sanctuary Site Easement

Los Guillicos Preserve

GAP 1	GAP 2
0%	98.04%
GAP 3	GAP 4
0%	1.96%

Agency Name: California State University Sonoma
Agency Type: State
Access Type: Restricted Access
Acres: 38.00
Management Stack: CPAD/KCED

Join CEI's events!

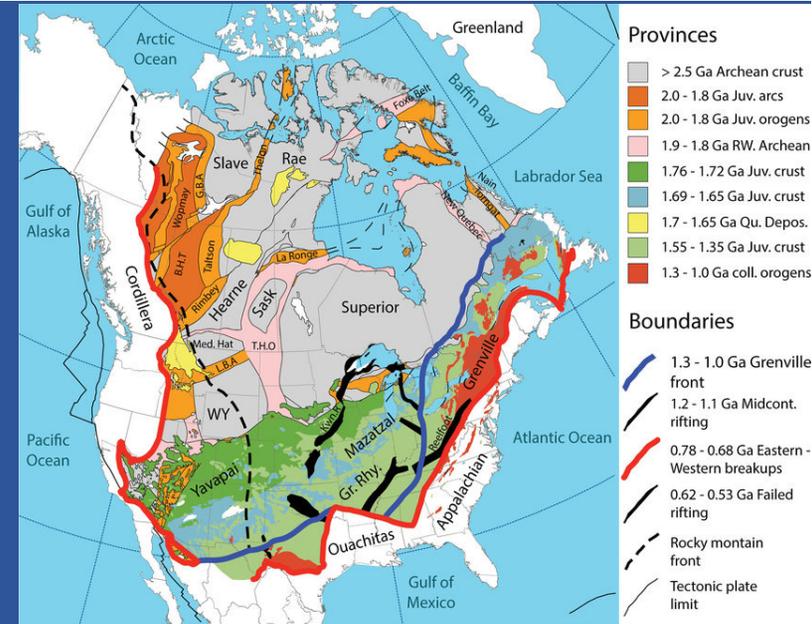


- <https://cei.sonoma.edu/calendar-events>
- <https://cei.sonoma.edu/visit-preserves-gardens>
- <https://experience.arcgis.com/experience/83b5c08cae8b47d3b7c623f2de1f0dcc>

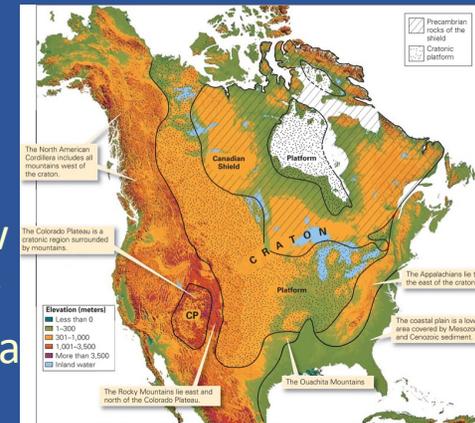
Recap

North America

- 2800-2500Ma Kenorland Supercontinent
- 2400-2200Ma Snowball Earth
- 1650-1630Ma Penokean Orogeny
- 2000-1400Ma Trans-Hudson Orogeny/Columbia “SC”
- 1800-1600Ma Yavapai , Mazatzal, Mojave Orogenies
- 1300 - 700Ma Grenvillian Orogenies = Rodinia “SC”
- 720 - 635Ma Final Snowball Earth
- 541 - 530Ma Cambrian Explosion
- 480 - 260Ma Pangaea forms



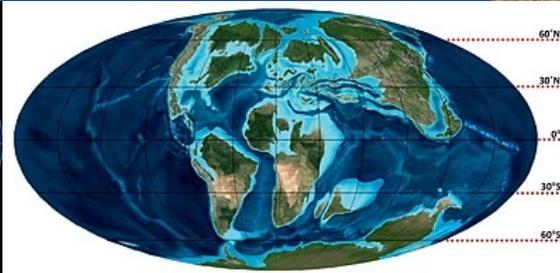
Only ~75% of National Parks have rock outcrops older than 200Mya: Voyageurs, Pipestone, Grand Teton, Yellowstone, Wind Cave, Glacier, Black Canyon of the Gunnison, Rocky Mountains, Joshua Tree, Grand Canyon, Death Valley, Saguaro, Isle Royale, Great Smoky Mountains, Shenandoah, Great Basin, Denali, Gates of the Arctic, Kobuk Valley, Wrangell-St. Elias, Sequoia, Kings Canyon, Yosemite, New River Gorge, Hot Springs, Acadia, Congaree, Pinnacles, Katmai, Lake Clark, Glacier Bay, Channel Islands, North Cascades, Indiana Dunes, Mammoth Caves, Cuyahoga Valley, Gateway Arch, Canyonlands, Guadalupe Mountains, Carlsbad Caverns, White Sands, Big Bend, Capitol Reef, Zion, Arches, Petrified Forest, Bryce Canyon



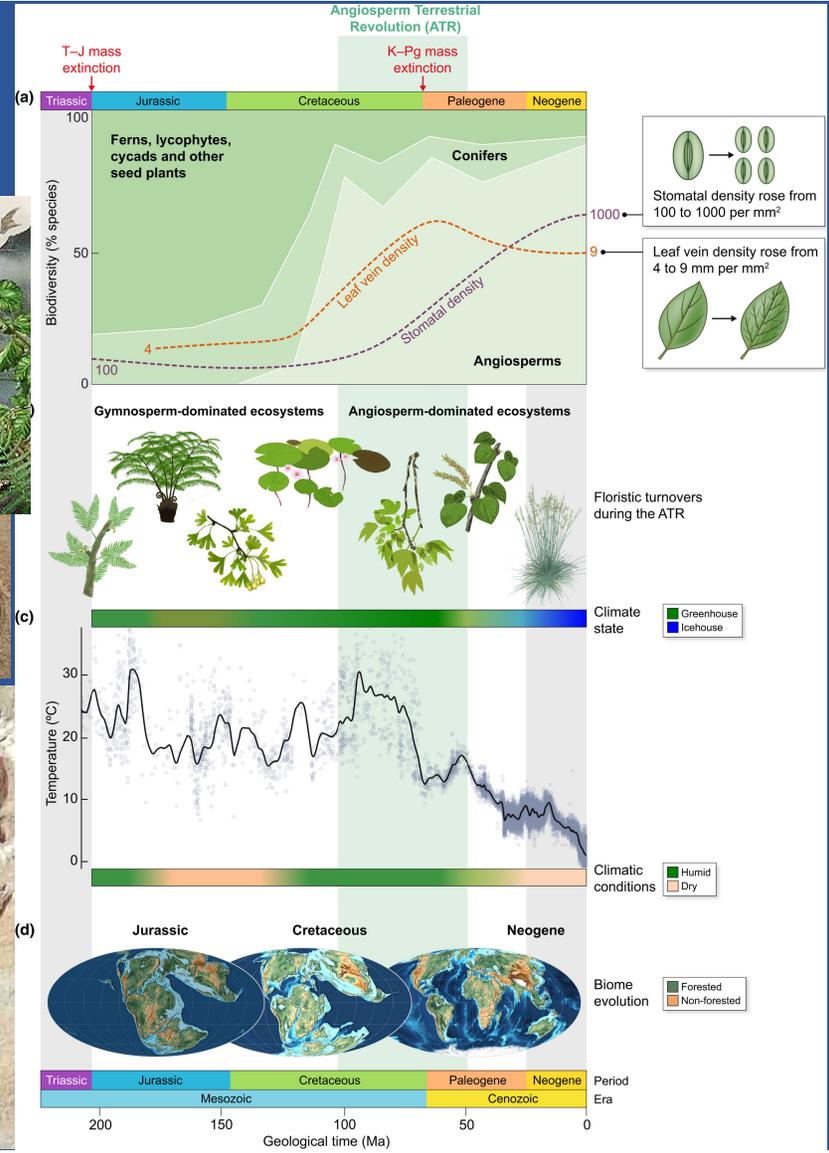
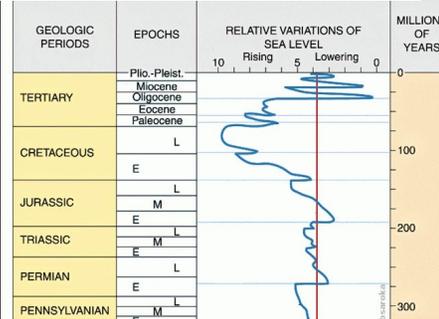
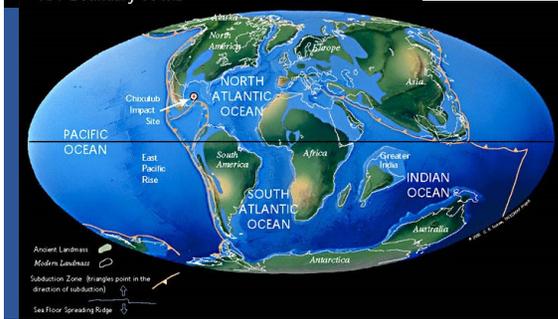
Jurassic-Cretaceous Rifting of Pangaea

201 - 145 - 66Ma Subtropical N. America

- Pangaea breaks-up
- CAMP LIP = Atlantic Ocean
- First angiosperms & birds
- Tropical forests widespread
- 75% mass extinction 66Ma



K/T Boundary 66 Ma



Appalachian Jurassic-Cretaceous Rocks

- 201-0Ma Atlantic Rifting & erosion

Mid to High Latitudes: humid subtropical to temperate

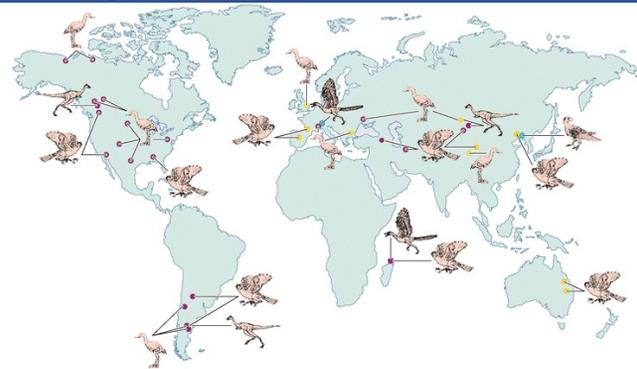
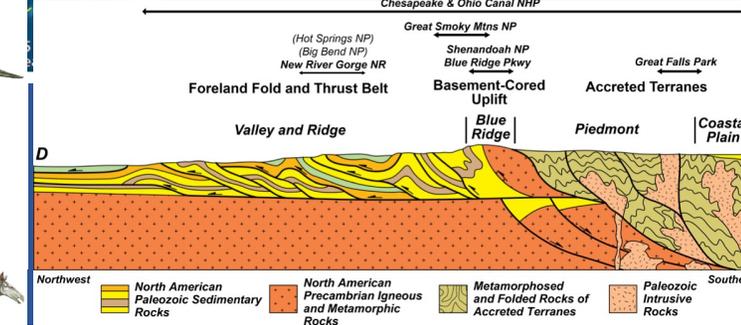
→ warm & humid subtropical + high sea levels

Buried Mesozoic Coastal Plain

- South Carolina: Congaree
- Florida: Everglades, Biscayne, Dry Tortugas
- Volcanic Arc
- Virgin Islands subaerial island building

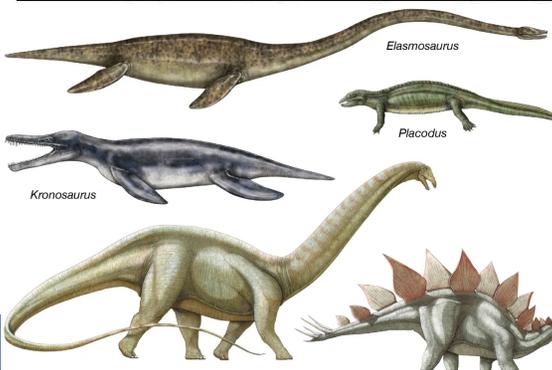


In the Triassic Period, Pangea began to split apart; the Gulf of Mexico and Atlantic Ocean opened. In the Jurassic, coastal mountains rose along the western coast of North America. By the Late Cretaceous, the entire continent was covered by a vast sea.



- Archaeopterygidae
- Alvarezsauridae
- Confuciusornithidae
- Enantiornithomorpha
- Ornithomorpha
- Late Jurassic
- Early Cretaceous
- Late Cretaceous

JURASSIC NEWARK BASIN (aborted rift system) EARLY ATLANTIC OCEAN (active rift system)



Midcontinent Jurassic-Cretaceous Rocks

- 230-165Ma Gulf Coast Rifting (not exposed)
- 165-0Ma Passive Margin, WIS, Gulf of Mexico Subduct
- 70-40Ma Laramide Orogeny

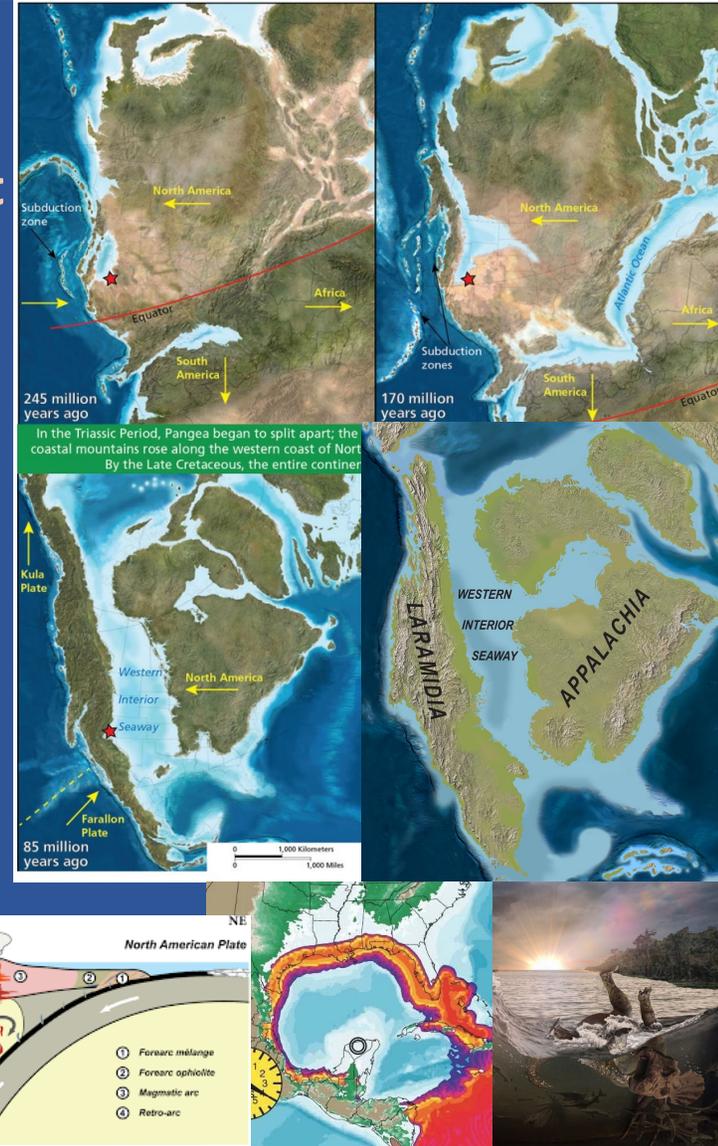
Mid to High Latitudes: semi-arid & seasonally wet → warm & humid + drowned by high sea levels

River Systems → Western Interior Seaway → Uplift

- Colorado: Rocky Mountains, Great Sand Dunes, Mesa Verde, Black Canyon of the Gunnison
 - Wyoming: Grand Teton, Yellowstone
- Shorelines & Depths of WIS
- North Dakota: Theodore Roosevelt
 - South Dakota: Wind Cave, Badlands
 - Texas: Big Bend

Gulf of Mexico Subduction

- Virgin Islands: Virgin Islands pillow basalts



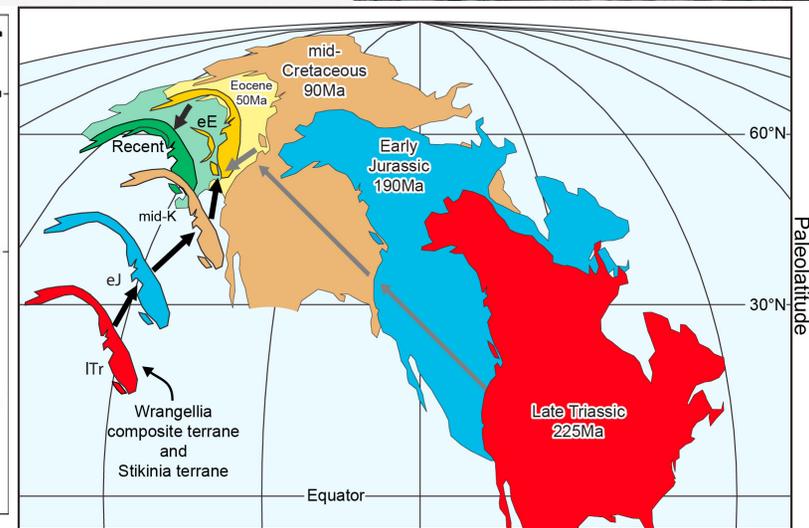
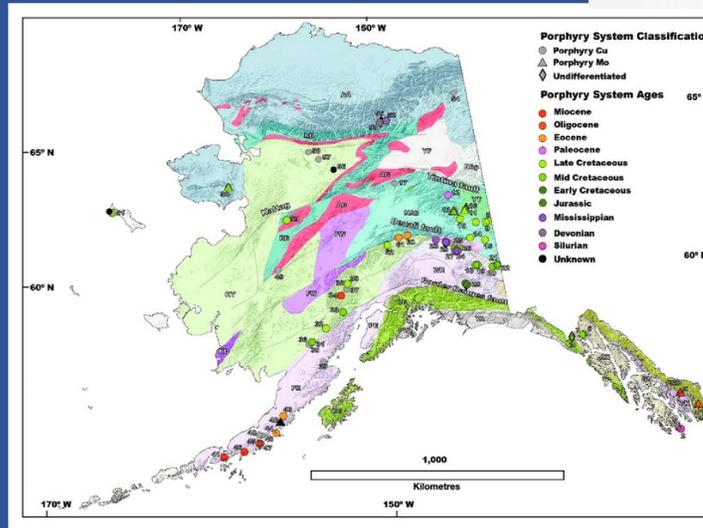
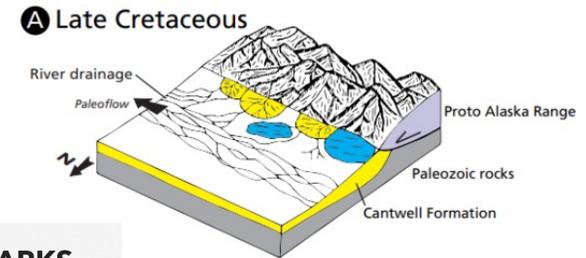
Alaskan Jurassic-Cretaceous Tropical Islands

- 200-170Ma Arc Accretion
- 160-145Ma Nevadan Orogeny
- 160-100Ma Brookian Orogeny
- 120-70Ma Wrangellia & Peninsula accretion

Mid-Latitudes: warm & humid + volcanic arcs

Volcanic Arc & Marine Environments

- Wrangell-St. Elias
- Lake Clark
- Katmai
- Denali (Dinosaurs!)
- Gates of the Arctic
- Glacier Bay
- Kenai Fjords
- Kobuk Valley



Pacific Coast Jurassic-Cretaceous Rocks

- 160-145Ma Nevadan Orogeny
- 140-50Ma Sevier Orogeny
- 70-40Ma Laramide Orogeny



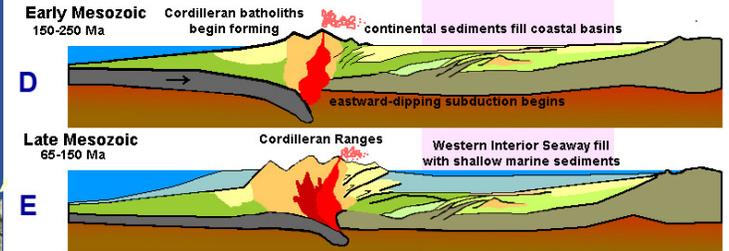
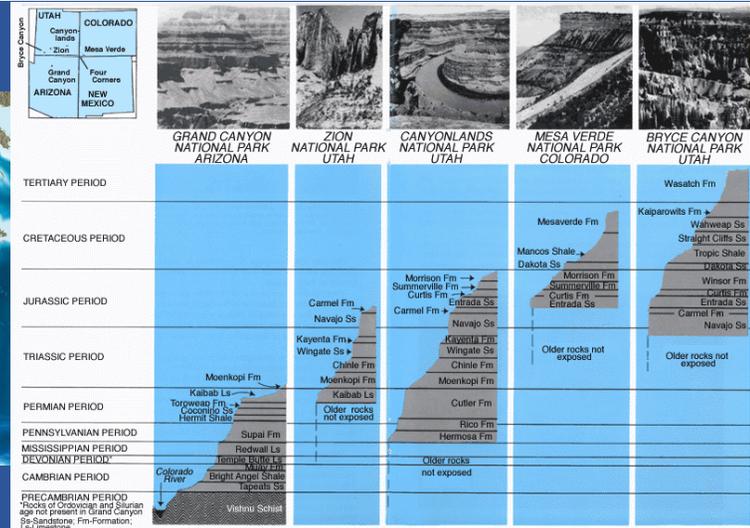
Mid to High Latitudes: hot & arid + rainy coastal subtropical → warm & humid

Coastal Plains & Shallow Seas ↔ Deserts & Rivers

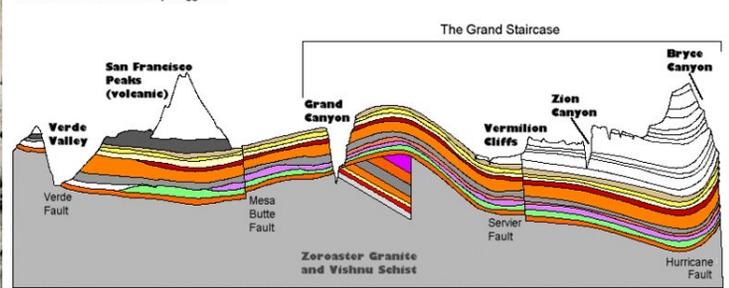
- Utah: Canyonlands, Arches, Capitol Reef, Zion Marine Shelf to Basin + Volcanic Arc
- California/Nevada: Great Basin, Death Valley, Pinnacles Redwood, Channel Islands

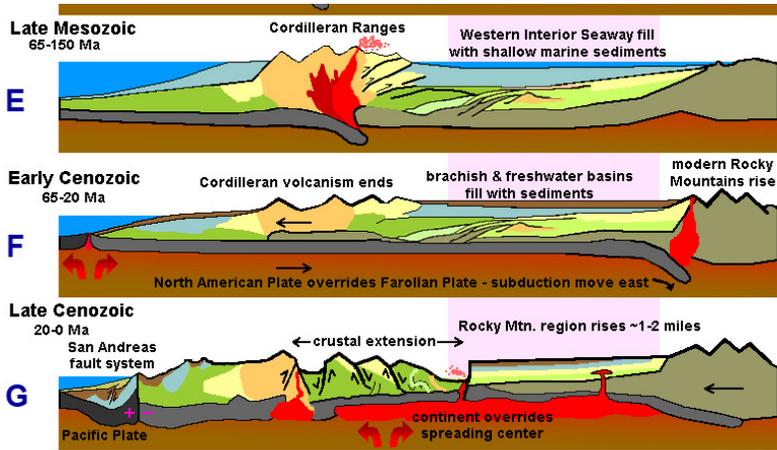
Volcanic Arc

- California: Yosemite, Sequoia, Kings Canyon
- Washington: North Cascades



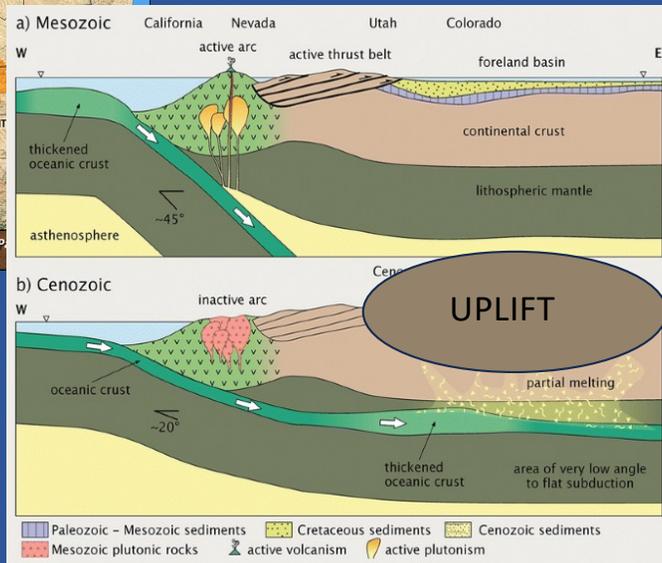
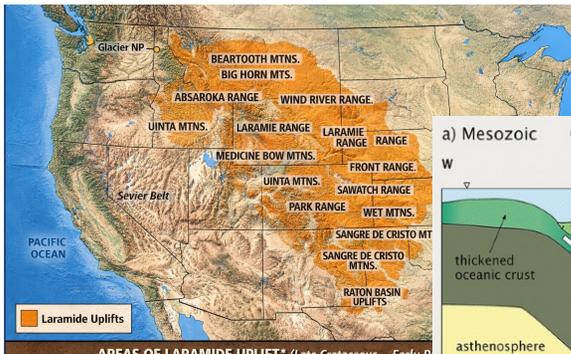
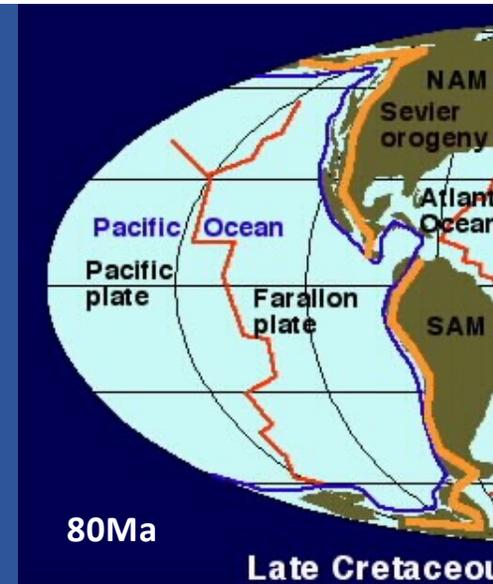
Grand Canyon Rock Layers Throughout the Colorado Plateau



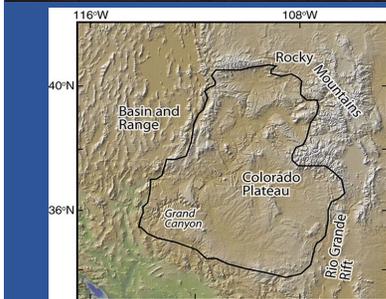


Laramide Orogeny

- 70-40Ma: demise of the Farallon Plate
- CO/WY/MT/ID/UT/NM/SD: Rockies, Colorado Plateau, San Cristo, Big Horns, Black Hills, Wind River, Absaroka...
- Wind Cave drained 50-40Ma

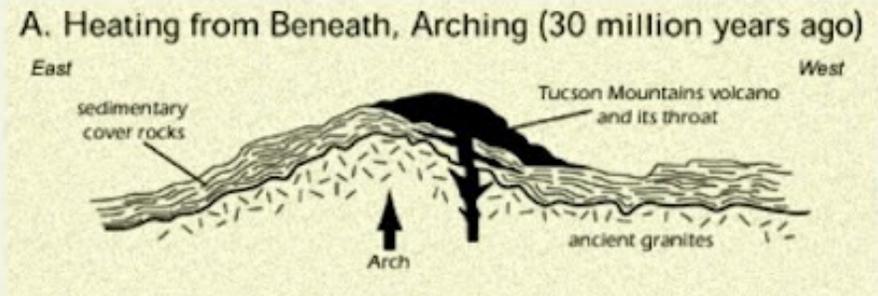
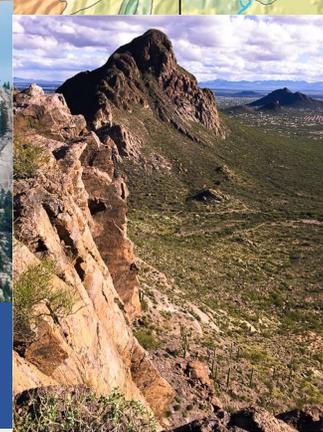
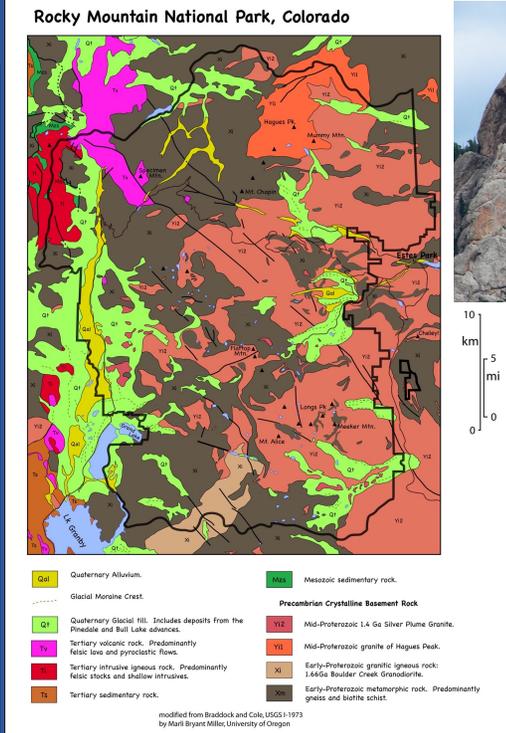
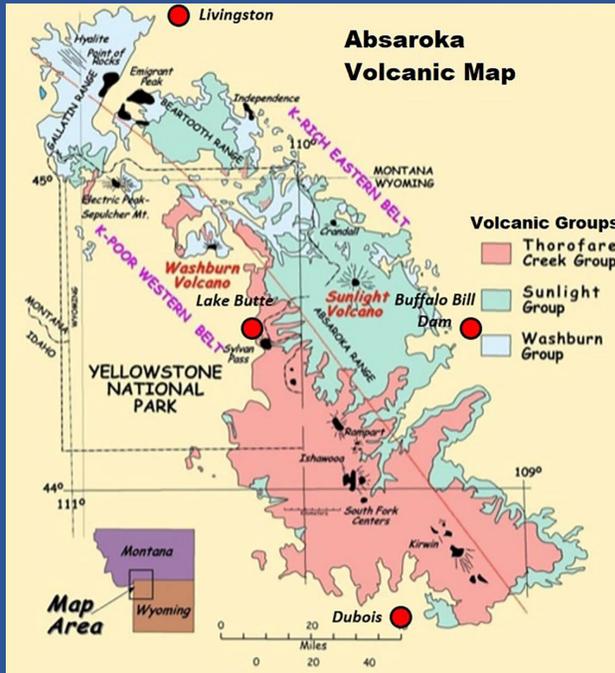
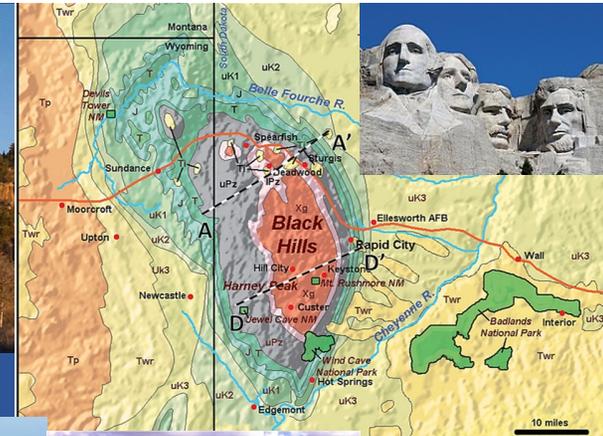
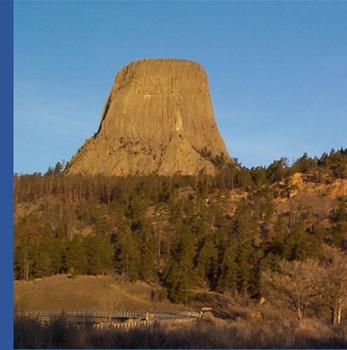


Video: <https://www.pbs.org/wgbh/nova/video/making-north-america-origins/>



Laramide Volcanism

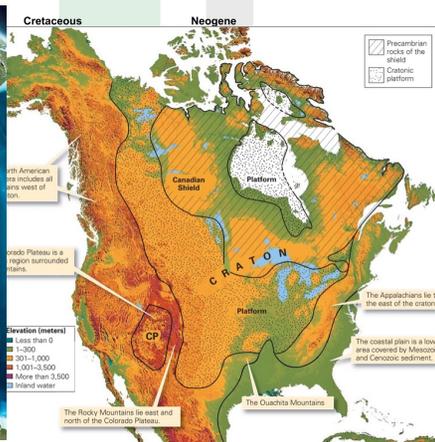
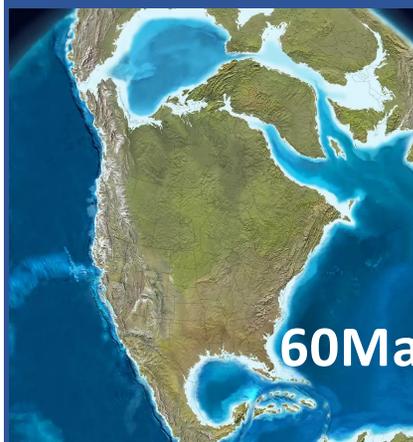
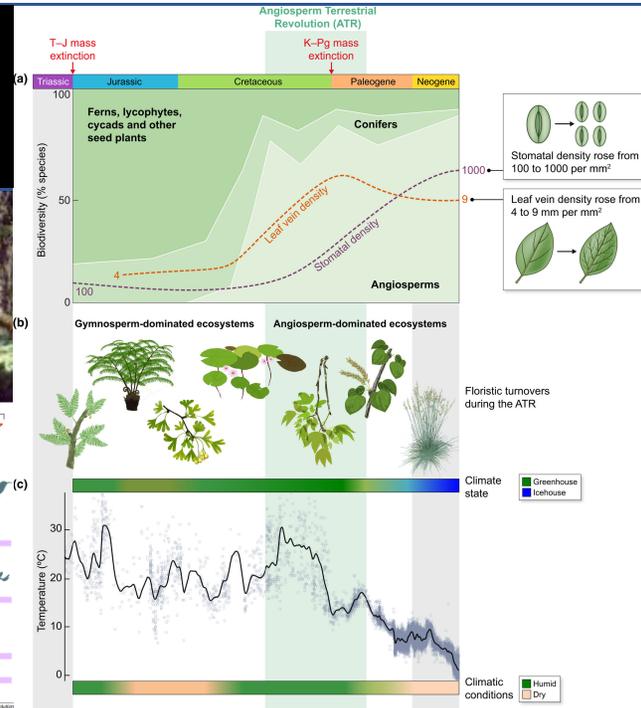
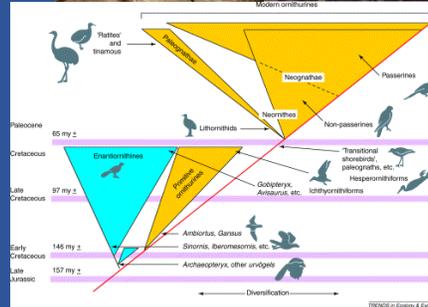
- AZ: ~70Ma Saguaro Tucson Mtn caldera
- CO: ~70-40Ma Rocky Mountain
- SD: ~50Ma Black Hills Devil's Tower intrusion
- WY/MT/ID: 55-43Ma Yellowstone + Grand Teton Absaroka Supergroup



Tertiary Transitions

66 - 23 - 2.58 Ma Hothouse → Icehouse

- Paleogene & Neogene Periods
- PETM & tropical → Antarctic ice age
- Himalayan + Alpine + Andean Orogens
- Formation of Isthmus of Panama → Great American Biotic Interchange
- East African Rift System → hominins
- Aridification & grassland expansion
- Bird & mammal radiation



Global temperatures		Phanerozoic: times of origin of plants and animals	
CENOZOIC	Quaternary		Holocene Pleistocene with alternating periods of glaciation and warm periods <i>Homo sapiens</i>
	Neogene		Pliocene Miocene Oligocene Eocene Paleocene Early humans <i>Sahelanthropus</i> Apes Monkeys Primates
	Paleogene		Mammals
MESOZOIC	Cretaceous		Late Cretaceous Early Cretaceous Angiosperms
	Jurassic		Late Jurassic (Malm) Middle (Dogger) Early (Lias) bird <i>Archaeopteryx</i> earliest Mammals (i. e. <i>Hadrocodium wui</i>)
	Triassic		Keuper Muschelkalk Buntsandstein Pterosaurs Fish dinosaurs Dinosaurs
PALAEOZOIC	Permian		Zechstein Rotliegend Reptiles Therapsids Sauropsids Synapsids first Amniotes Giant dragonflies
	Carboniferous		Pennsylvanian Vegetation that became coal Mississippian
	Devonian		Cycads Lycophytes Ferns Horsetails (Equisetidae) first terrestrial vertebrates <i>Ichthyostega</i>
PALAEOZOIC	Silurian		early land plants in riparian zones first bony fish (Osteichthyes) Placodermi
	Ordovician		all life forms are still aquatic Cephalopods
	Cambrian		new developments: brain eyes with lenses segmentation Bilateria Radiata Arthropods e.g. Trilobites Brachiopods, snails first vertebrates Chordates Annelids, Mussels Echinoderms, Tunicates Jellyfish, first corals
Precambrian		Archaea Bacteria Algae Parazoa Ediacara Fauna	Ediacara fauna

10 Minute Break!

Video link: https://www.youtube.com/watch?v=g_iEWvtKcuQ

Video link: <https://www.youtube.com/watch?v=lva1m8cl9-Q>

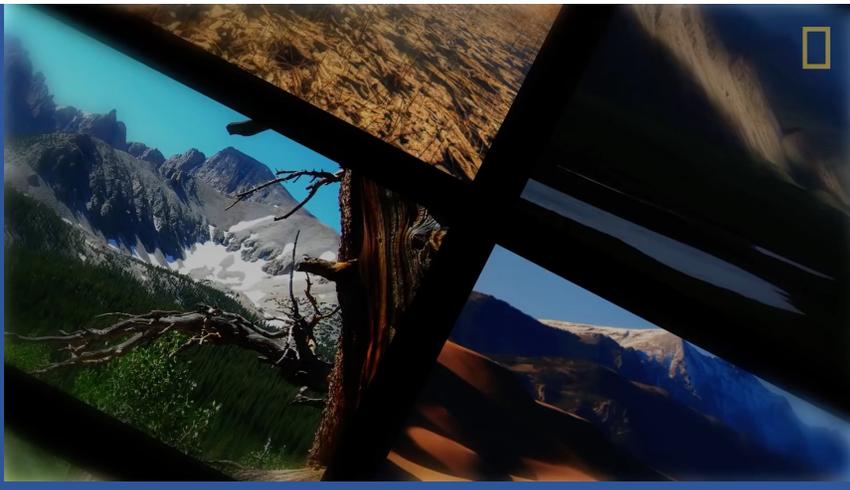


PLATE TECTONICS, PALEOGEOGRAPHY, and ICE AGES (Modern World - 540 Ma)

© 2016, C. R. Scotese

Appalachian Coast Tertiary Rocks

- 201-0Ma Atlantic Rifting & erosion

Mid Latitudes: warm & humid subtropical → cooling

Erosion of mountains & establishment of modern river systems

Shallow Marine → Slow Regression

- Florida: Everglades Megalodon Fossils 25-5Ma → wetlands; Biscayne, Dry Tortugas

Shallow Marine → Shoreline → River System

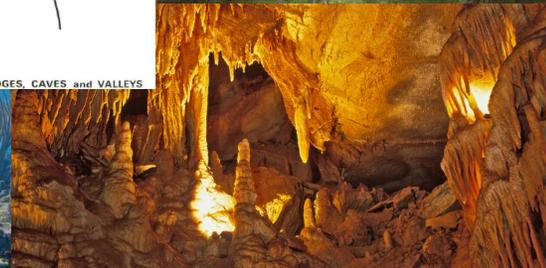
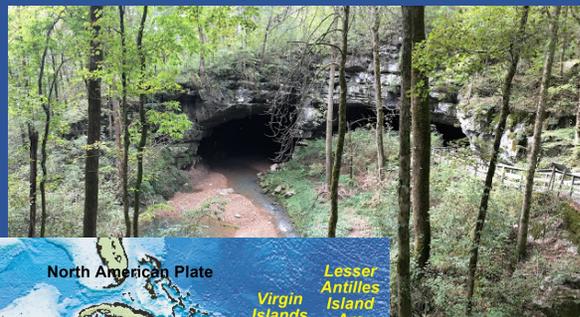
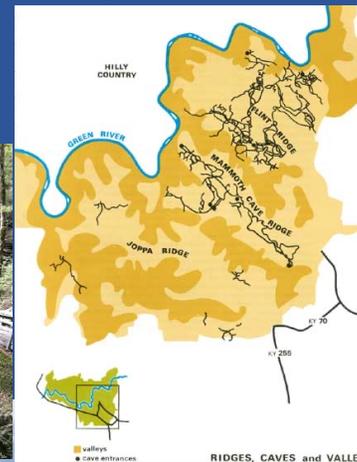
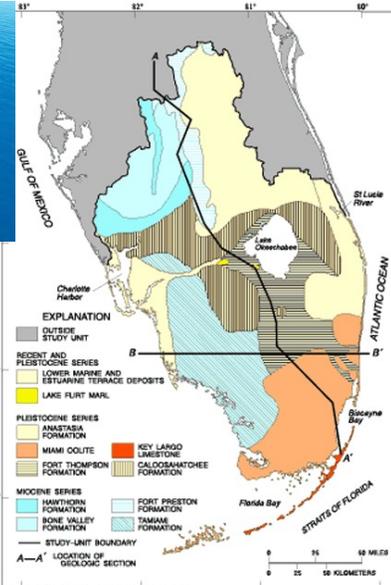
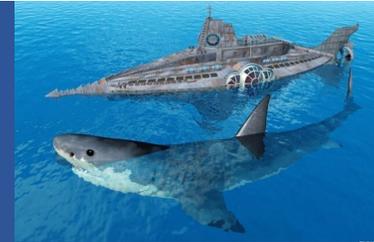
- South Carolina: Congaree

Uplift & Erosion

- Kentucky: Mammoth Caves karst formation ~10Ma

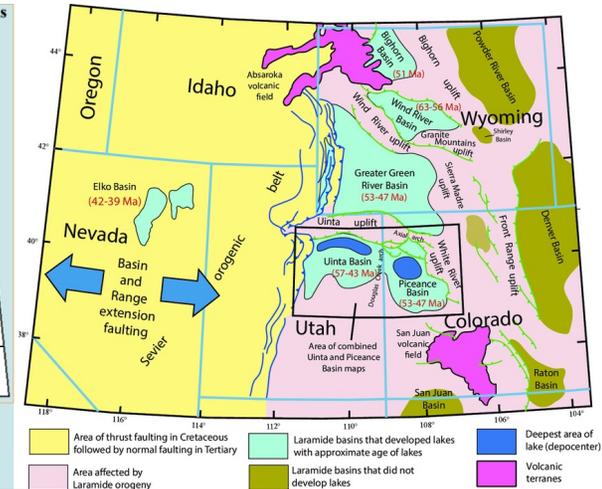
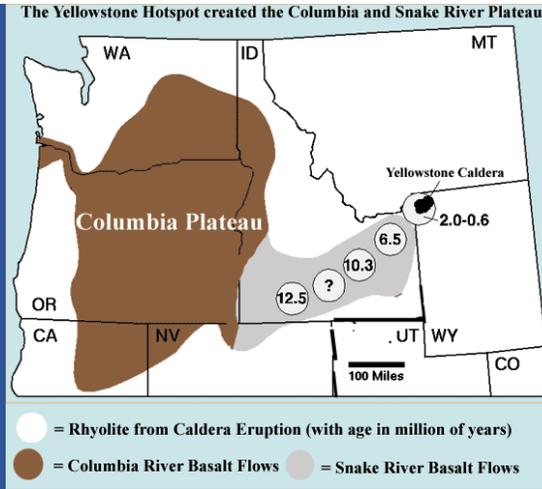
Volcanic Arc

- Virgin Island building 100-30Ma



Midcontinent Tertiary Rocks

- 165-0Ma Gulf Coast Passive Margin
 - 70-40Ma Laramide Orogeny
- Mid Latitudes: warm & subtropical → increased seasonality → cooler & drier → semi-arid → arid

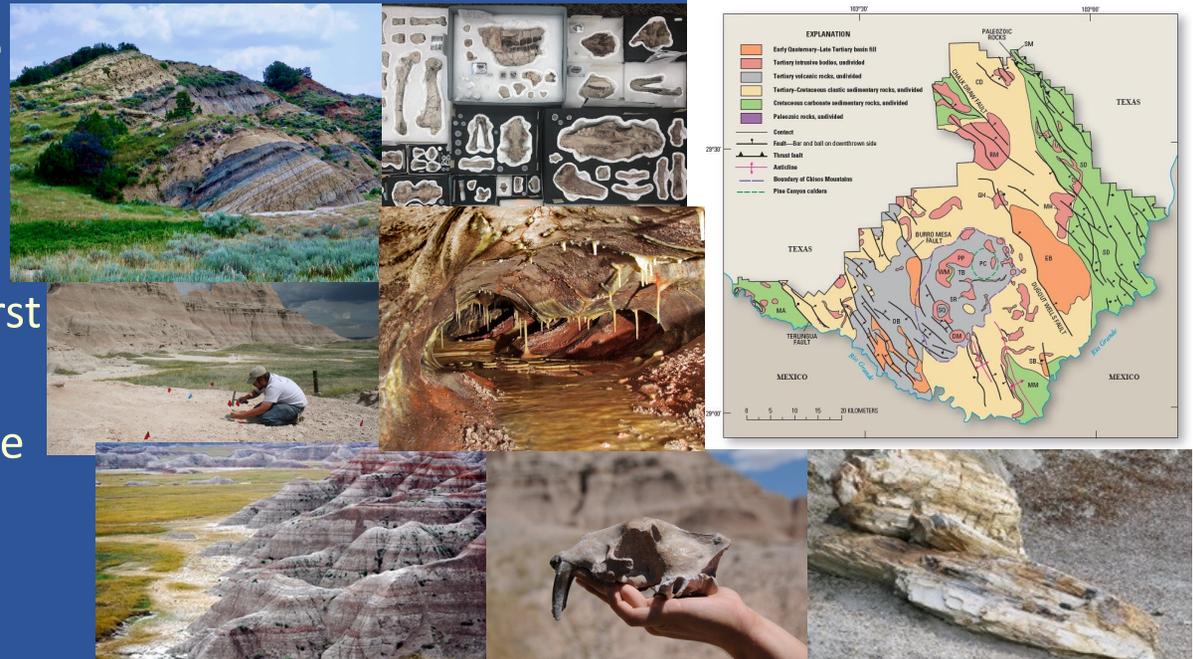


Eroded Sediment from the Laramide Uplift + Volcanic Ash → Rivers +/- Swamps → Forests → Grasslands

- ND/SD: Theodore Roosevelt & Badlands fossils + coal, Wind Cave karst

Rocky Mountains Uplift + Volcanism

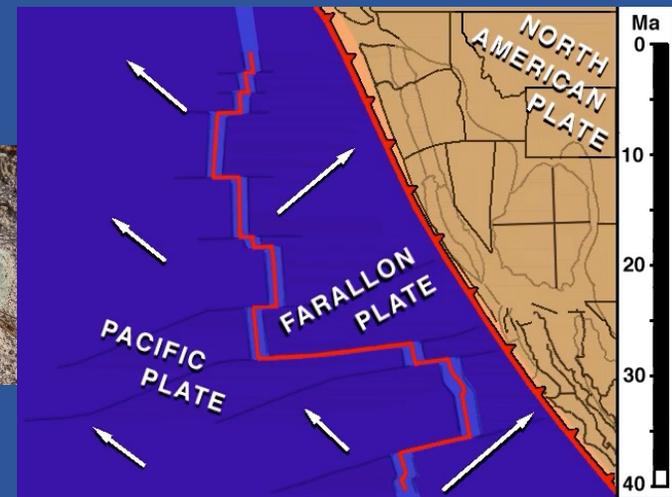
- MT/WY/ID/TX/CO: ~16Ma Yellowstone hotspot, Grand Teton, Glacier, Rocky Mtns, Black Canyon of the Gunnison, Big Bend, Great Sand Dunes



Tertiary Formation of the San Andreas

- 70-40Ma Laramide Orogeny
- ~30-0Ma San Andreas Transform Boundary
- ~20-0 Ma Sierra Nevadas Uplift

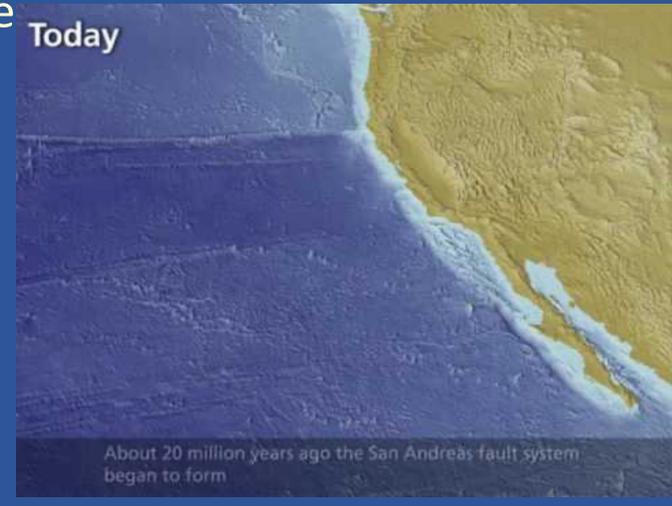
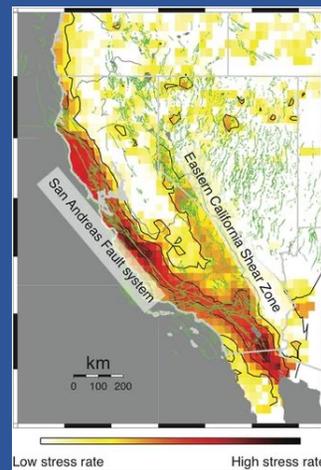
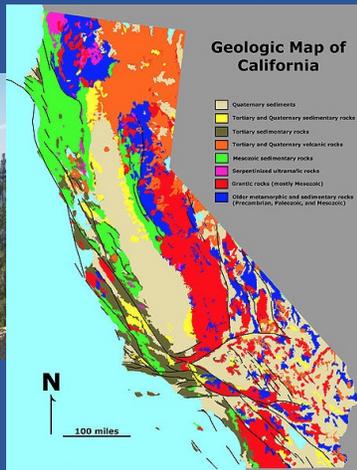
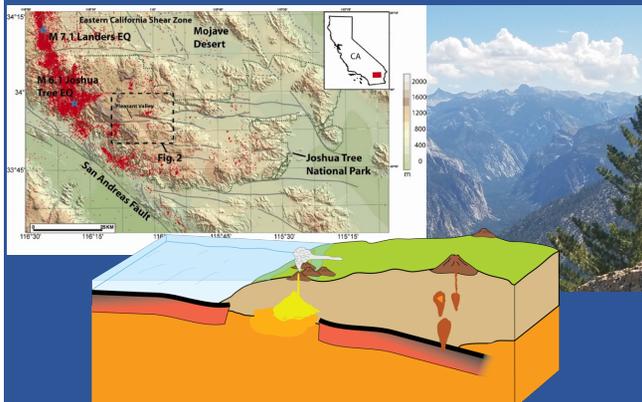
Mid Latitudes: warm & humid → ↑ seasonality
 → cooler → mediterranean-wet maritime



Video link:
<https://www.youtube.com/watch?v=IDTBY5WDELg>
 Video Link:
<https://www.youtube.com/watch?v=9xVkJounTDwE>

Laramide Orogeny → subduction of divergent boundary → transform boundary uplift, volcanism, & smearing

- CA: Pinnacles, Redwood, Channel Islands, Joshua Tree, Yosemite Sequoia, Kings Canyon



Tertiary Uplift of the Colorado Plateau

- 70-40Ma Laramide Orogeny → Crustal Extension
- Mid Latitudes: warm & humid → increased seasonality → cooler & drier → semi-arid → arid

Laramide Uplift + minor deformation → Magmatic Uplift → Delamination Uplift & Colorado River links to Gulf of CA 5-6Ma + Volcanism 34-0.001Ma

- UT: Arches, Canyonlands, Zion, Capitol Reef, Bryce Canyon shallow lakes & wetlands
- CO: Mesa Verde
- AZ: Petrified Forest (Jemez Lineament), Grand Canyon

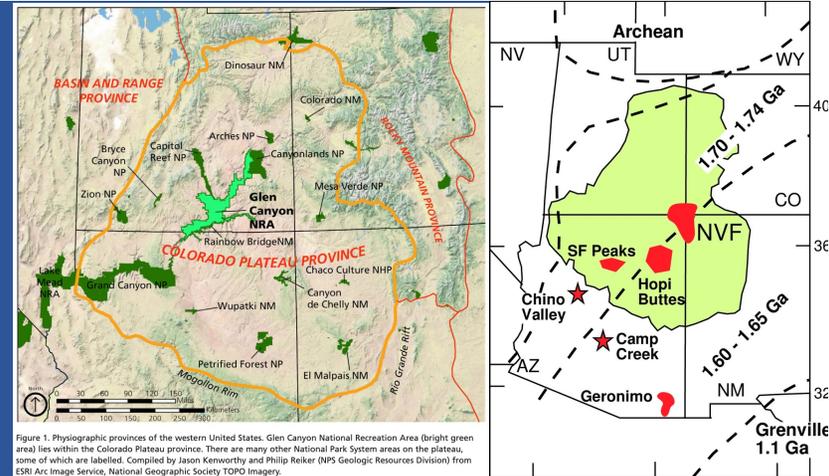
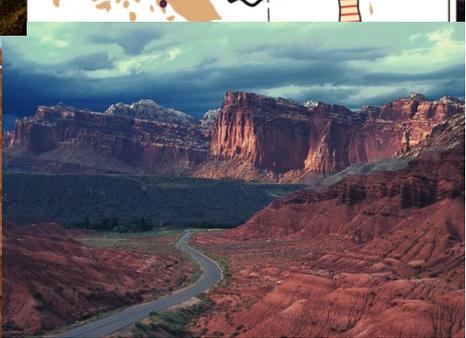
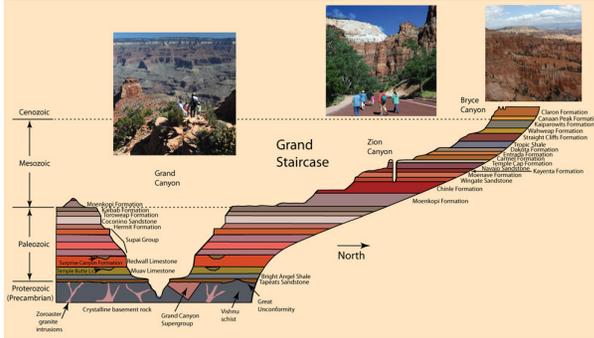
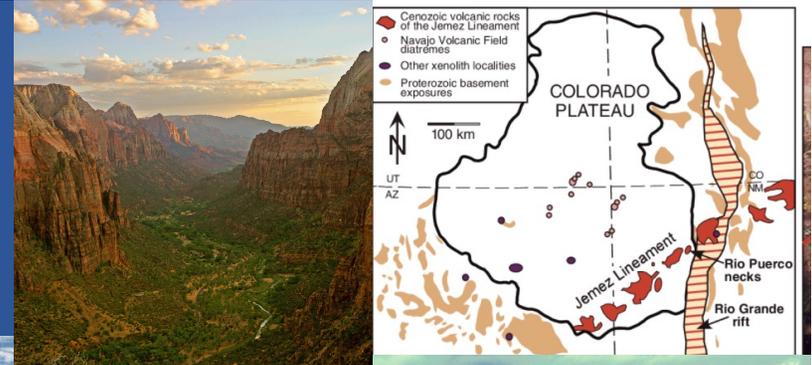


Figure 1. Physiographic provinces of the western United States. Glen Canyon National Recreation Area (bright green area) lies within the Colorado Plateau province. There are many other National Park System areas on the plateau, some of which are labeled. Compiled by Jason Kenworthy and Philip Reiker (NPS Geologic Resources Division) from ESRI Arc Image Service, National Geographic Society TOPO Imagery.



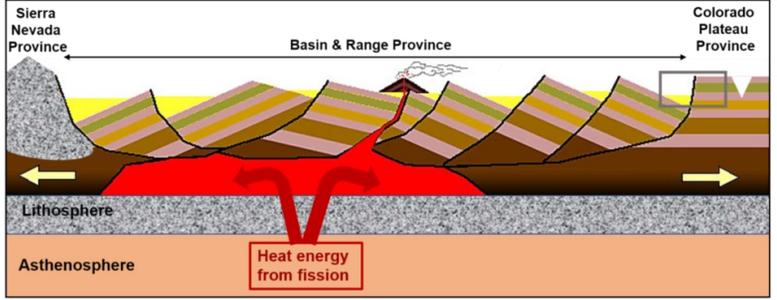
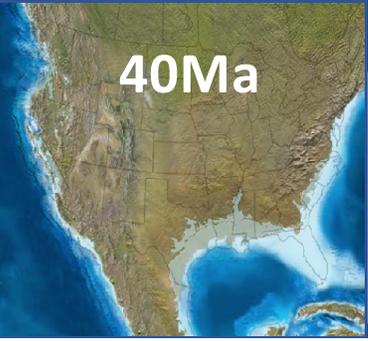
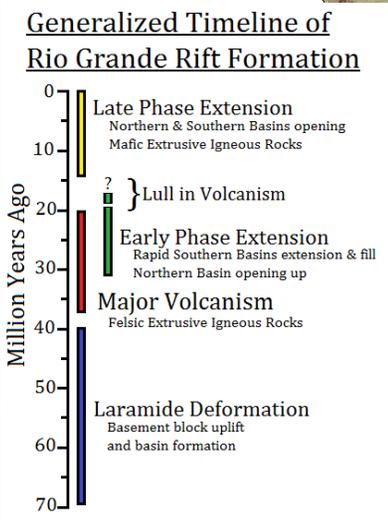
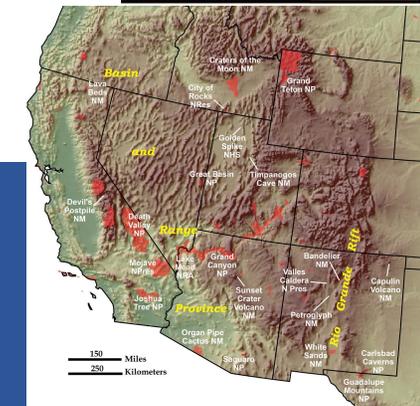
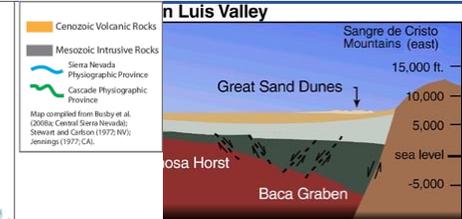
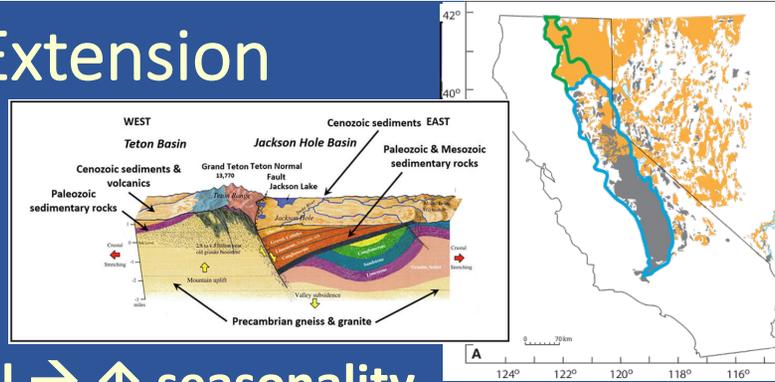
Tertiary Western Extension

- 140-50Ma Sevier Orogeny
- 70-40Ma Laramide Orogeny
- ~36-0 Ma Rio Grande Rift
- ~30-0 Ma Basin & Range

Mid Latitudes: warm & subtropical → ↑ seasonality
 → cooler & drier → semi-humid/semi-arid → arid: alluvial fan, eolian

Sevier → Laramide Orogeny → extensional faulting + volcanism

- NM/TX/CO/WY/UT/AZ/NV/CA: Big Bend, Guadalupe Mountains, Carlsbad Caverns, White Sands, Great Sand Dunes, Death Valley, Joshua Tree, Saguaro, Great Basin, Grand Canyon, Zion, Bryce Canyon, Grand Teton



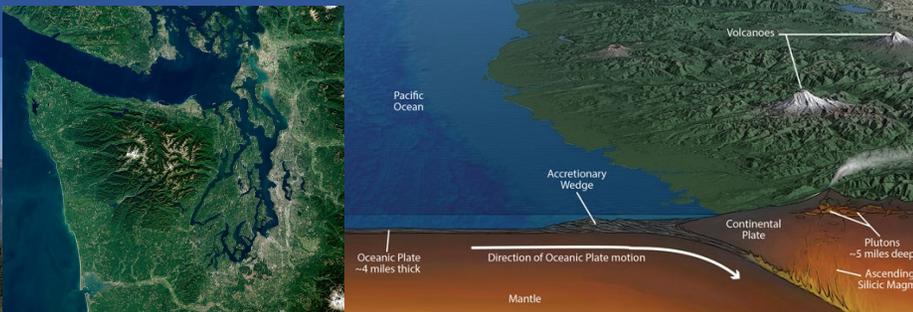
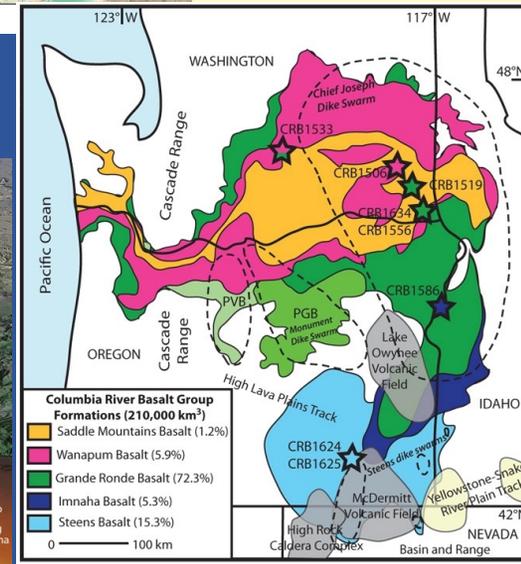
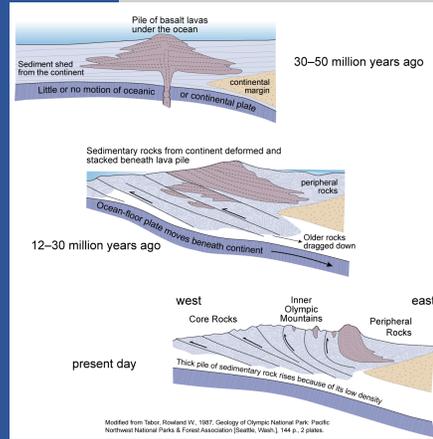
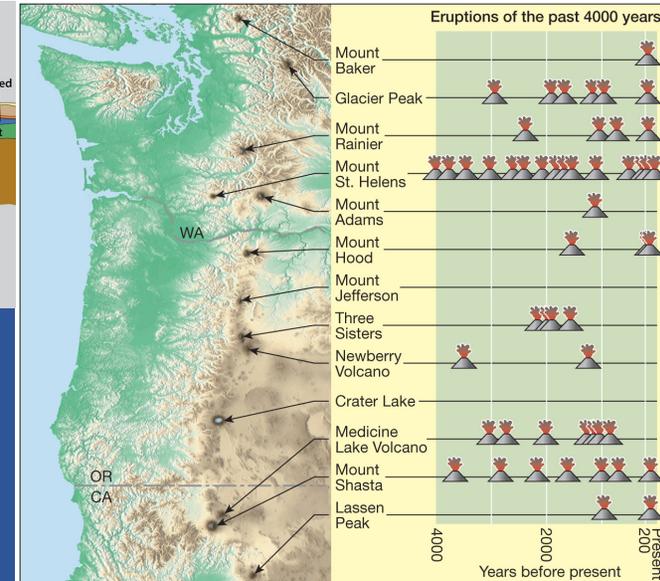
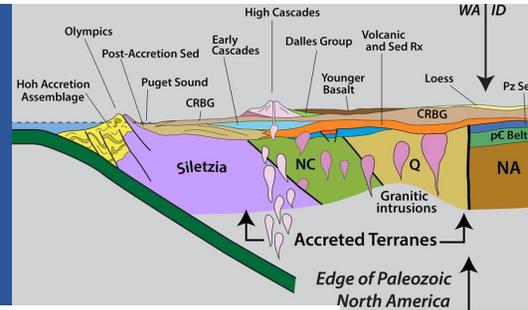
Tertiary Cascadia Orogeny

- 70-40Ma Laramide Orogeny
- ~35-0Ma Cascadia Orogeny

Mid Latitudes: warm & humid →
 ↑ seasonality → cooler → wet
 maritime climate

Laramide Orogeny → Farallon
 Plate fragmentation (Juan de
 Fuca) → Cascadia Orogeny

- CA/OR/WA: Lassen Volcanic,
 Crater Lake, Mount Rainier, North
 Cascades, Olympic



Tertiary Terrestrial Alaska

- ~60-0Ma Aleutian Arc
- ~48Ma Pacific Plate rotation
- ~34-10Ma Yakutat Microplate accretion + Denali Fault

Mid Latitudes: warm & humid → ↑ seasonality → cooler
 → wet temperate maritime climate → sub-Arctic

Volcanic Arc & Marine Environments + Eastern Strike-Slip

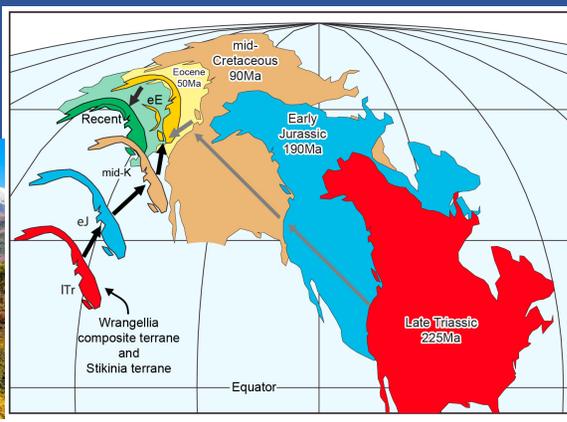
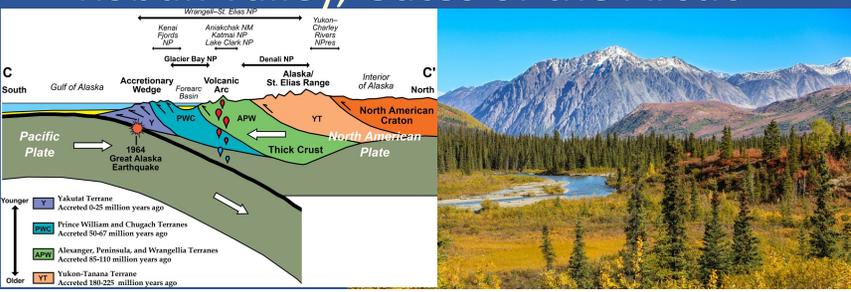
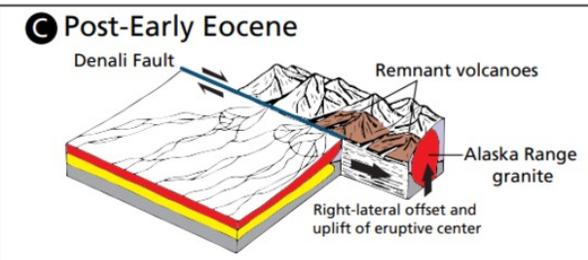
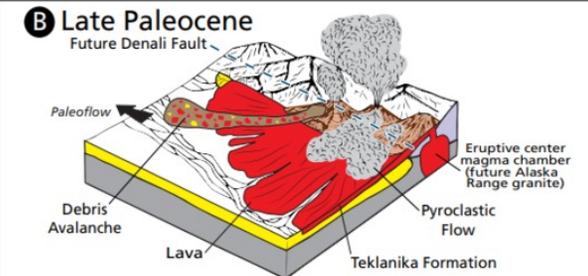
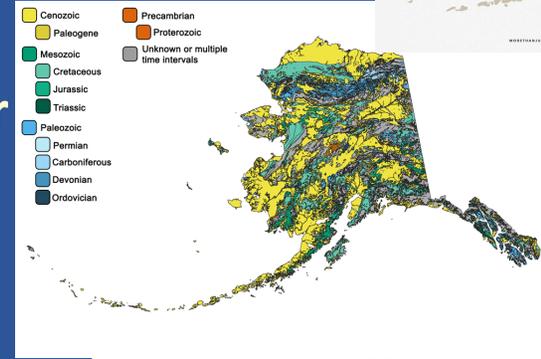
- Katmai, Lake Clark, Glacier Bay, Kenai Fjords, Wrangell-St. Elias
- ## Microplate Accretion, Strike-Slip Faulting & Rivers

- Denali, Wrangell-St. Elias

Eroding Mountain Belt & Sediments

- Kobuk Valley, Gates of the Arctic

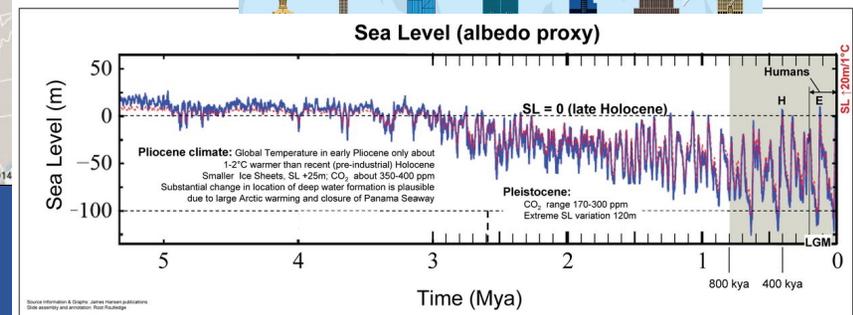
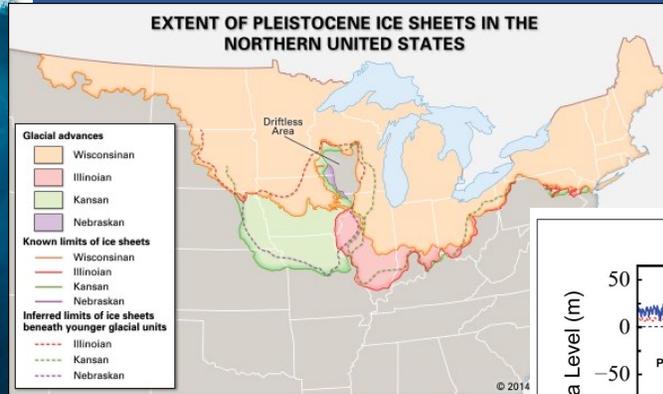
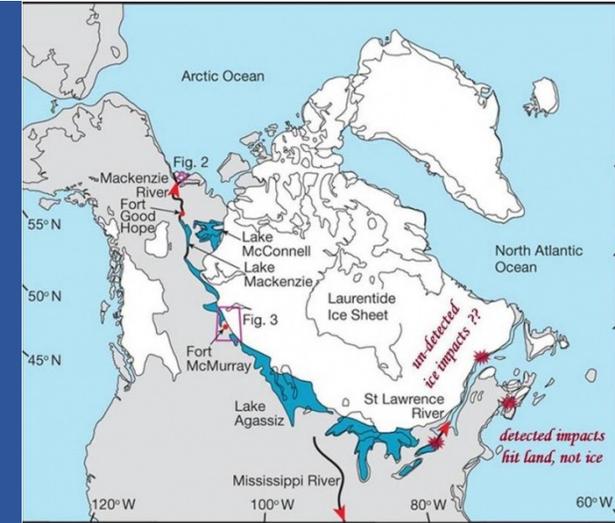
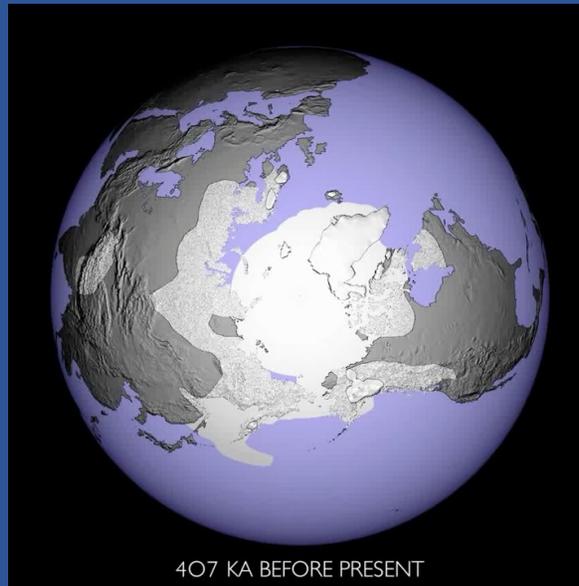
ALASKA NATIONAL PARKS
OF THE UNITED STATES OF AMERICA



Quaternary Ice Age

2.58 - 0Ma Glaciated N. America

- Neogene orogenies continue
- Interglacial-glacial cycles
- Pleistocene megafauna
- Homo sapiens ~300,000ybp



Quaternary Volcanism

Cascade Volcanic Arc: Juan de Fuca Subduction

- WA/CA/AZ/NV/UT: Mount Rainier, North Cascades, Crater Lake, Lassen Volcanic, Grand Canyon, Death Valley, Zion

Aleutian Volcanic Arc

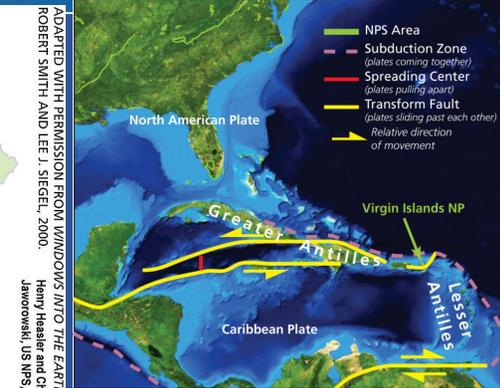
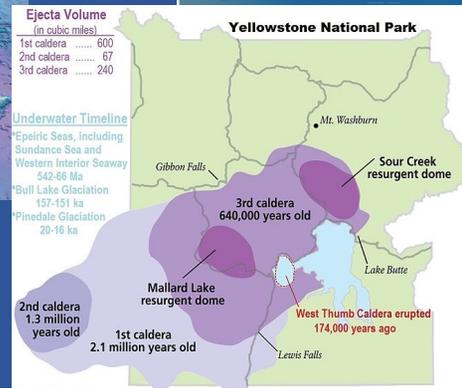
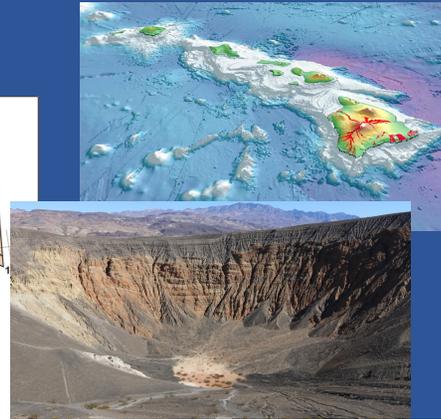
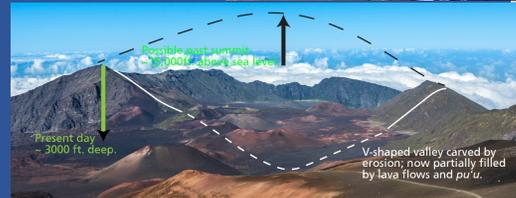
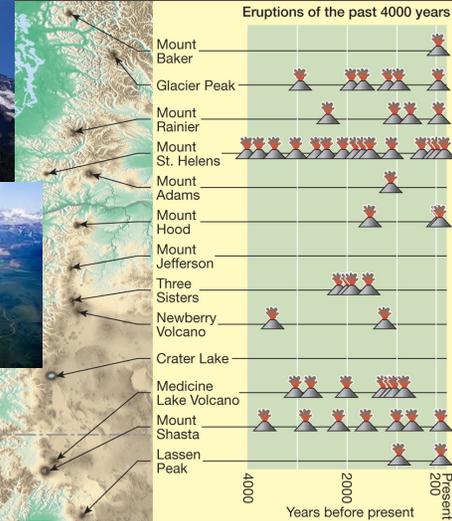
- AK: Wrangell-St. Elias, Lake Clark, Katmai

Lesser Antilles Volcanic Arc

- Virgin Islands: Virgin Islands

Hot Spots

- MT/WY/ID/HI/Samoa: Yellowstone, Hawaii Volcanoes, Haleakala, American Samoa



Quaternary Ice Age

LGM~26.5kya: glacial till, outwash, erratics, moraines, fjords, U-shaped valleys, striations, glacial rebound

Laurentide Ice Sheet

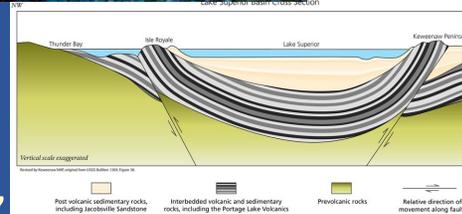
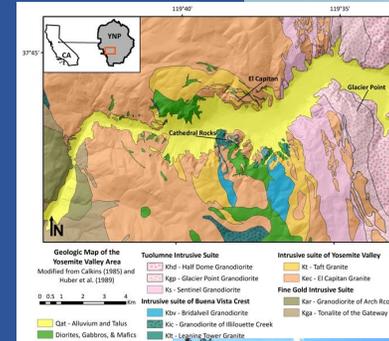
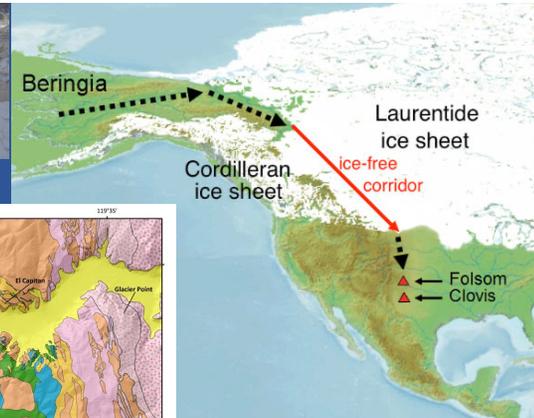
- ME/OH/IN/MI/MN: Acadia, Cuyahoga Valley (Lake Erie), Indiana Dunes (Lake Michigan), Isle Royale (Lake Superior), Voyageurs (Lake Agassiz)

Cordilleran Ice Sheet [modern active glaciers]

- MT/WA/AK: Glacier (Lake Missoula), North Cascades, Olympic, Glacier Bay, Kenai Fjords, Wrangell-St. Elias

Alpine glaciers

- MT/WY/ID/CO/UT/NV/CA/OR/AK/HI: Grand Teton, Yellowstone, Great Sand Dunes, Rocky Mountains, Great Basin, Yosemite, Sequoia, Kings Canyon, Lassen Volcanic, Crater Lake, Mount Rainier, Gates of the Arctic, Denali, Lake Clark, Katmai, Haleakala, Hawaii Volcanos



Quaternary Ice Age Sediments & Meltwater

Alternating Wet & Dry Glacial-Interglaciation Intervals

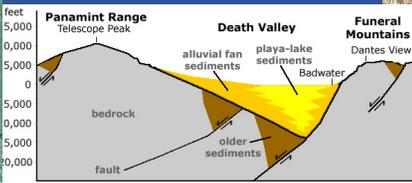
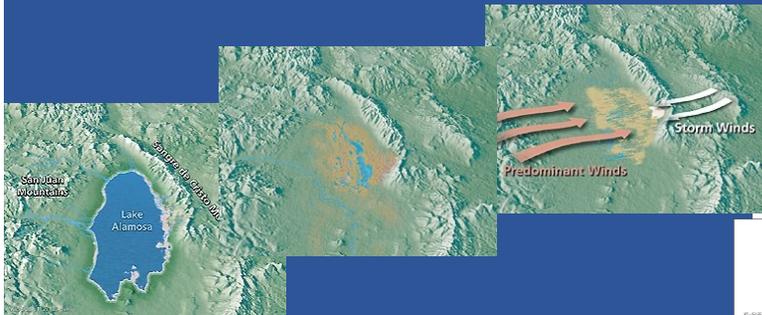
Periglacial Climate (no active glaciers)

- VA/WV/KY/TN/ND/SD/MO/UT: Bryce Canyon, Capitol Reef, Shenandoah, New River Gorge, Mammoth Caves, Great Smoky Mountains, Theodore Roosevelt, Badlands, Wind Cave, Gateway Arch, Zion



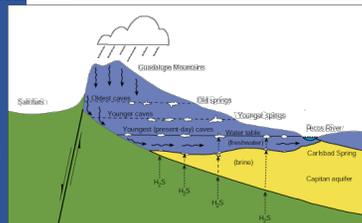
Lakes & Rivers

- CA/NM/CO/UT/AZ/TX/OH/AR: Joshua Tree, Carlsbad Caverns, Cuyahoga Valley, Black Canyon of the Gunnison, Mesa Verde, Arches, Canyonlands, Petrified Forest, Grand Canyon, Calsbad Caverns, Guadalupe Mountains, Saguaro, Pinnacles, Hot Springs, Redwood



Pluvial Lakes → Eolian Systems

- TX/NM/CO/AZ/CA/AK: Big Bend, Death Valley (Lake Manly), Great Sand Dunes (Lake Alamosa), White Sands (Lake Otero), Kobuk Valley

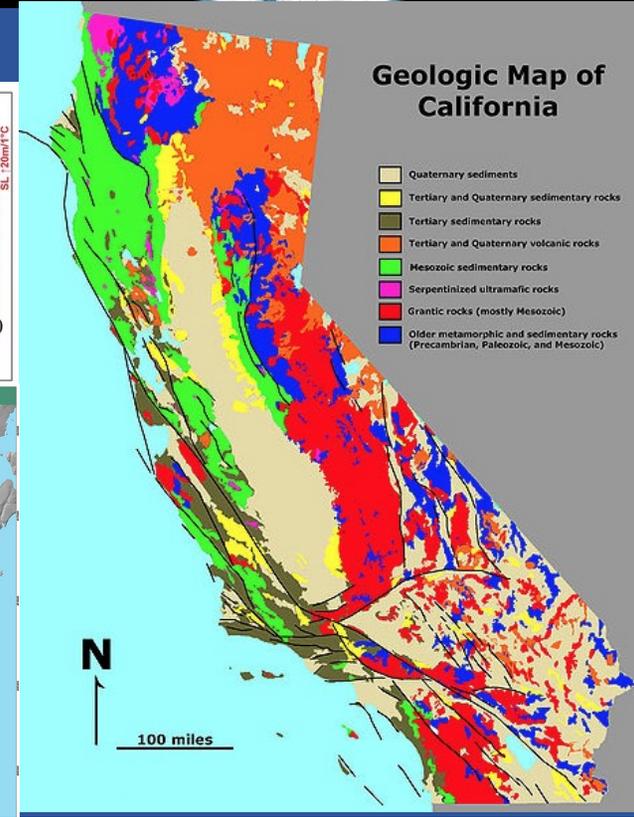
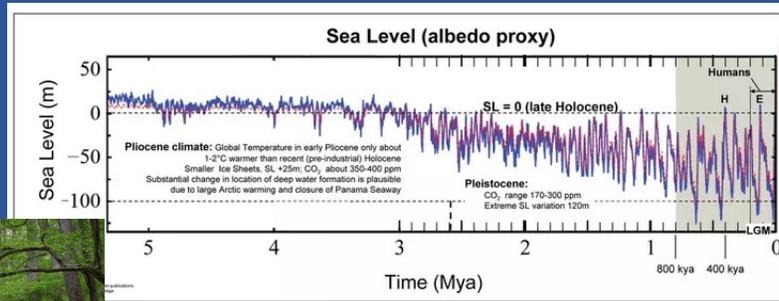
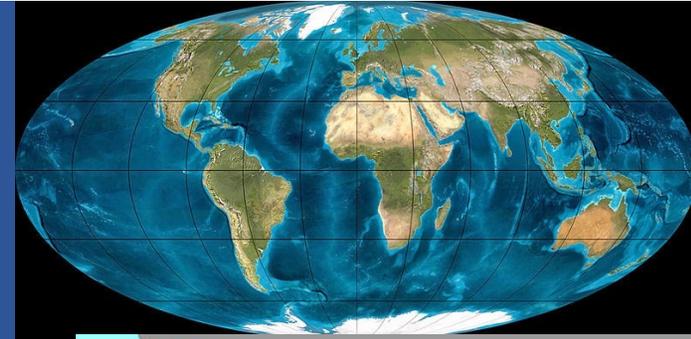


Quaternary Sea Level Fluctuation

Ice Age Sea Level Fluctuation + Wetter Climate

Strongly Influenced by Ice Age Sea Level Fluctuation

- FL/SC/CA/ME+: Biscayne, Dry Tortugas, Everglades, Congaree, Channel Islands, Acadia, American Samoa, Virgin Islands



Appreciating Earth

Nature Walks & Talks with:

SSU Center for Environmental Inquiry

- Check out CEI's upcoming events!
<https://cei.sonoma.edu/calendar-events>
- Join the CEI Newsletter!
<https://lp.constantcontactpages.com/sl/V5CtdaY>



Appreciating Earth

- Sign up for AE newsletters!
www.appreciatingearth.com/contact

