Geological Wonders of Yellowstone National Park, Wyoming

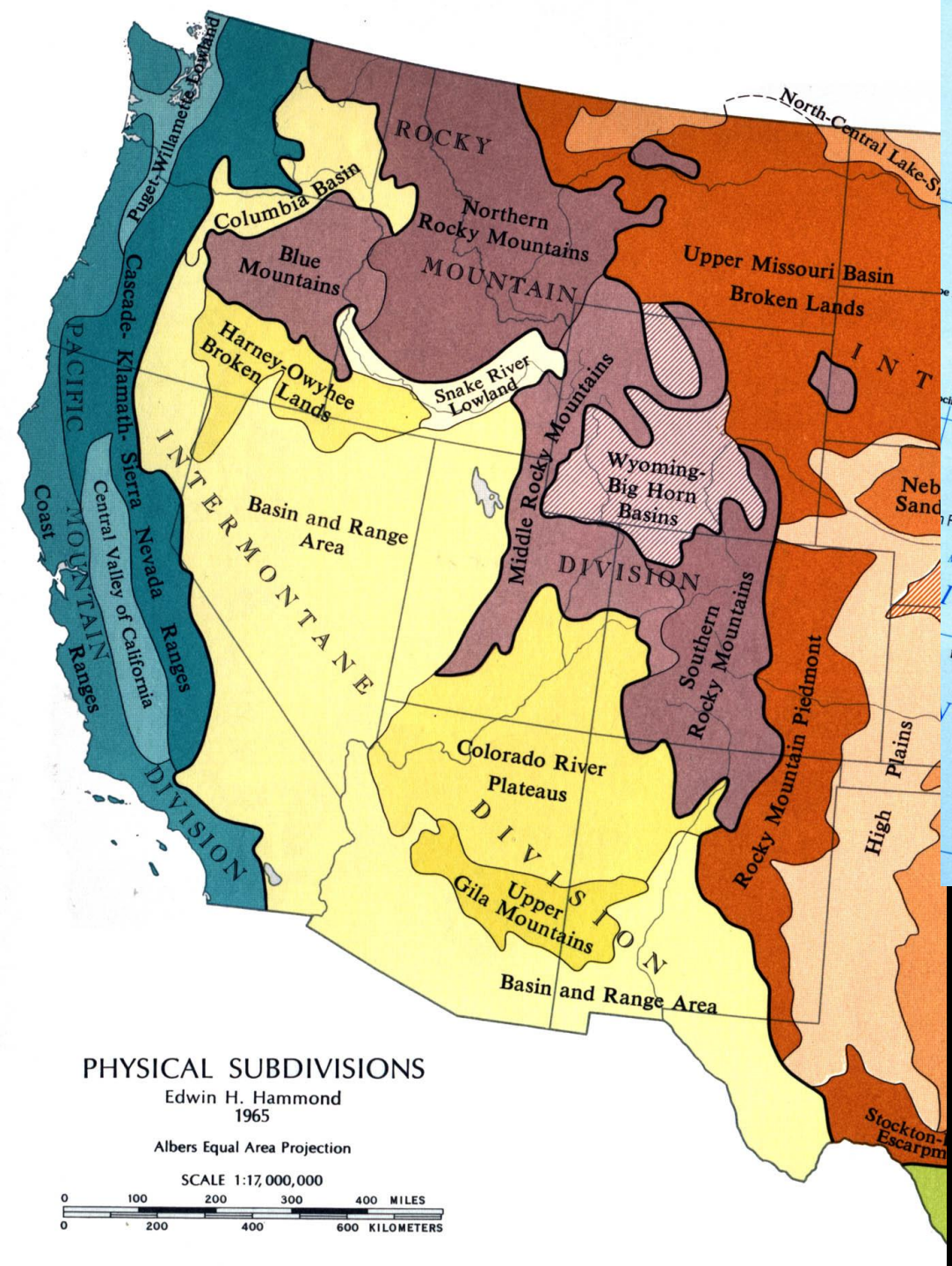
New York Mineral Club
10 October 2007

Charles Merguerian

Yellowstone IMAX

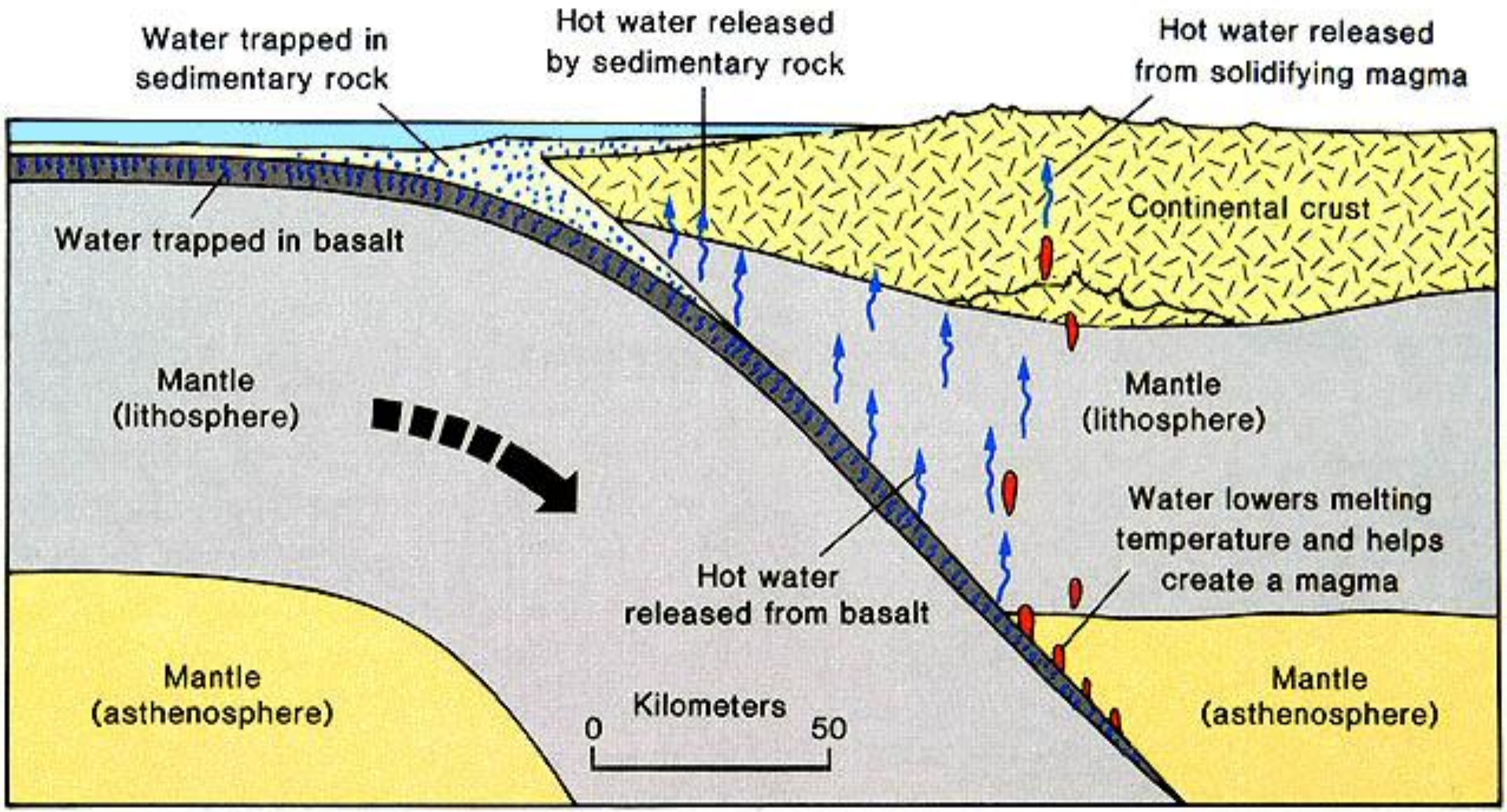
Hofstra University
Geology 280C
Geology For Teachers and Travelers

22-29 July 2006

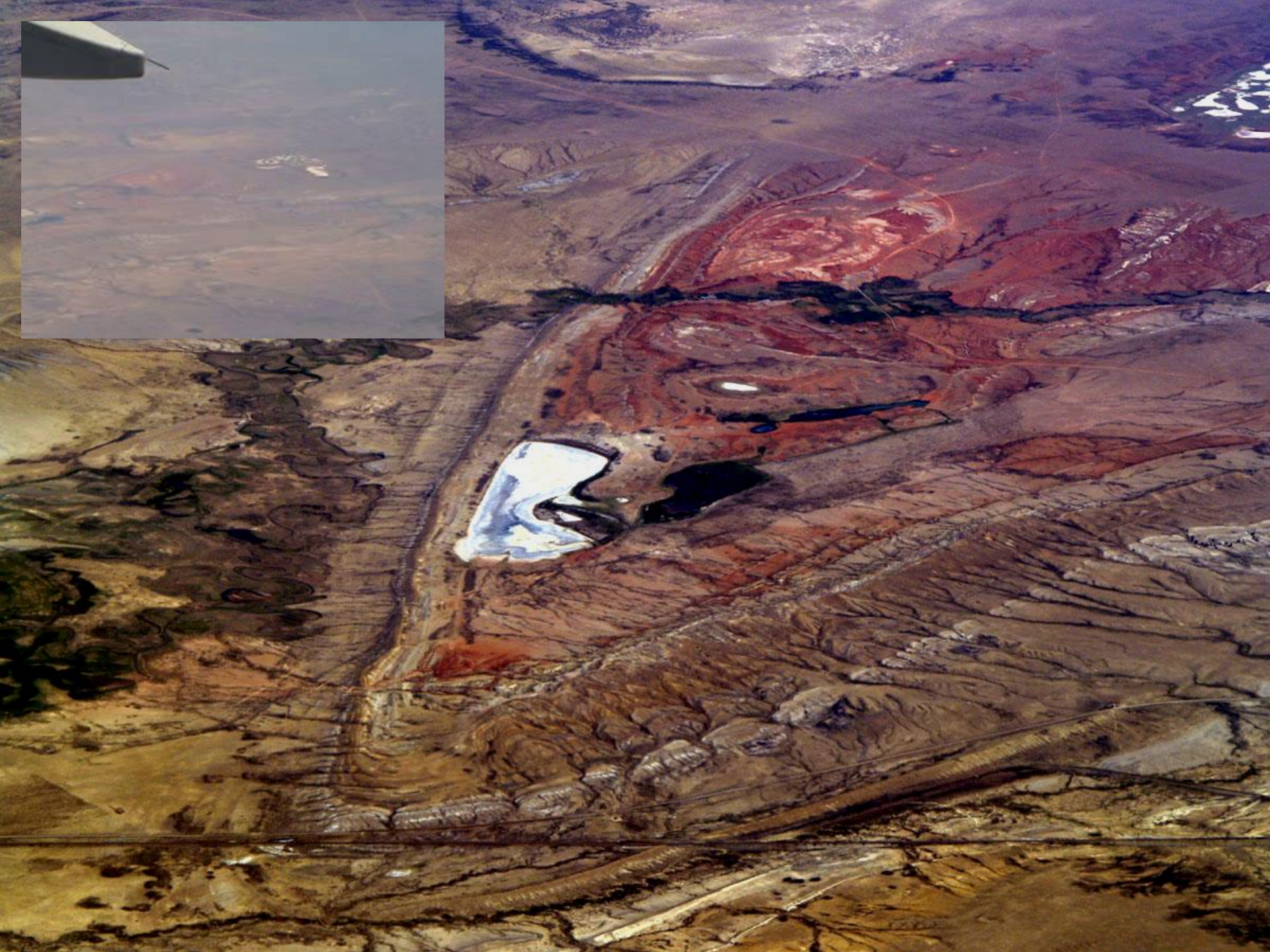

ROCKY MOUNTAIN DIVISION
Columbia Basin
Blue Mountains
Northern Rocky Mountains
Upper Missouri Basin Broken Lands
Harney-Owyhee Broken Lands
Snake River Lowland
Middle Rocky Mountains
Wyoming-Big Horn Basins
Basin and Range Area
INTERMONTANE DIVISION
Southern Rocky Mountains
Rocky Mountain Piedmont
High Plains
Colorado River Plateaus
Upper Gila Mountains
Basin and Range Area
PACIFIC MOUNTAIN DIVISION
Puget-Willamette Lowland
Cascade-Klamath-Sierra Nevada Ranges
Central Valley of California
Coast Ranges
North-Central Lake-S
Stockton-
Escarpm
PHYSICAL SUBDIVISIONS
Edwin H. Hammond
1965
Albers Equal Area Projection
SCALE 1:17,000,000
0 100 200 300 400 MILES
0 200 400 600 KILOMETERS


Vancouver
Cape Flattery
Seattle
Portland
WASHINGTON
OREGON
IDAHO
MONTANA
Columbia Plateau
Wyoming Basin
NEVADA
Great Basin
UTAH
COLORADO
Colorado Plateau
CALIFORNIA
Sierra Nevada
Coast Ranges
Mojave Desert
ARIZONA
NEW MEXICO
Rocky Mountains
Great Plains
Denver
Los Angeles
San Diego
Phoenix
El Paso
Tijuana
Pt. Conception
Channel Islands
San Francisco

Movement of water at convergent boundary




A319



Well ... Are You Going to
Tell Them About the Tetons?

Grand Tetons

9 Ma Tetons Fault Zone (30,000’ Offset = 1 cm/yr)

Grand Tetons

Grand Teton Range

Paleozoic Strata

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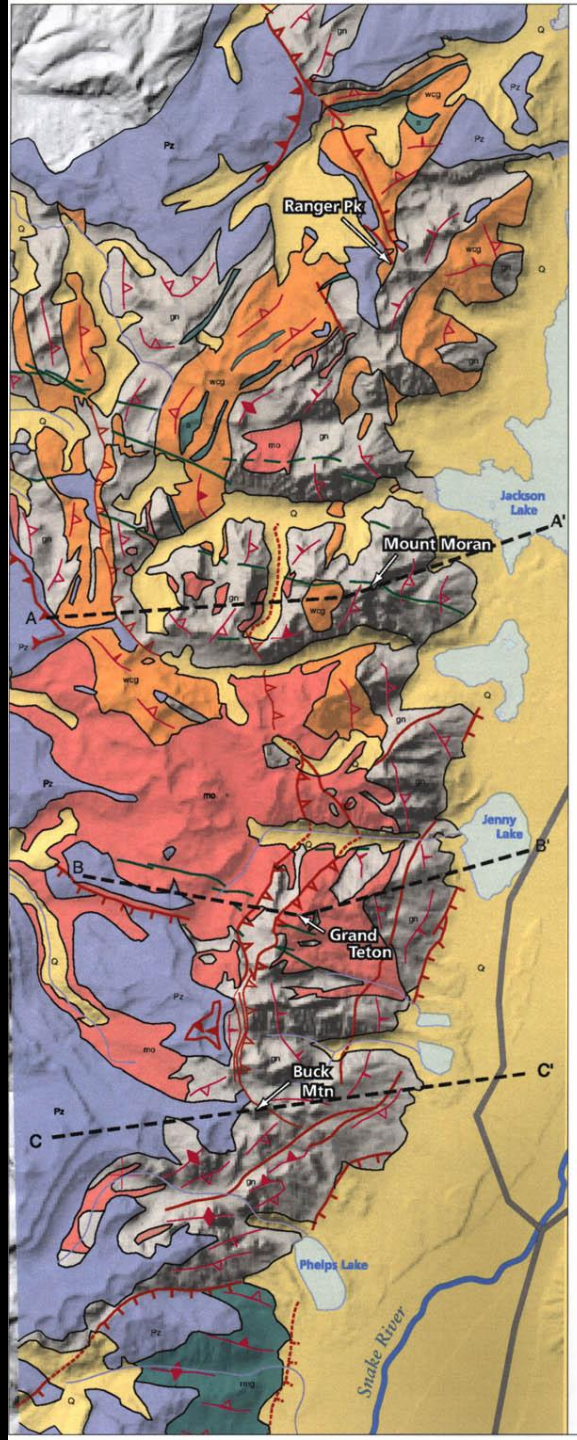
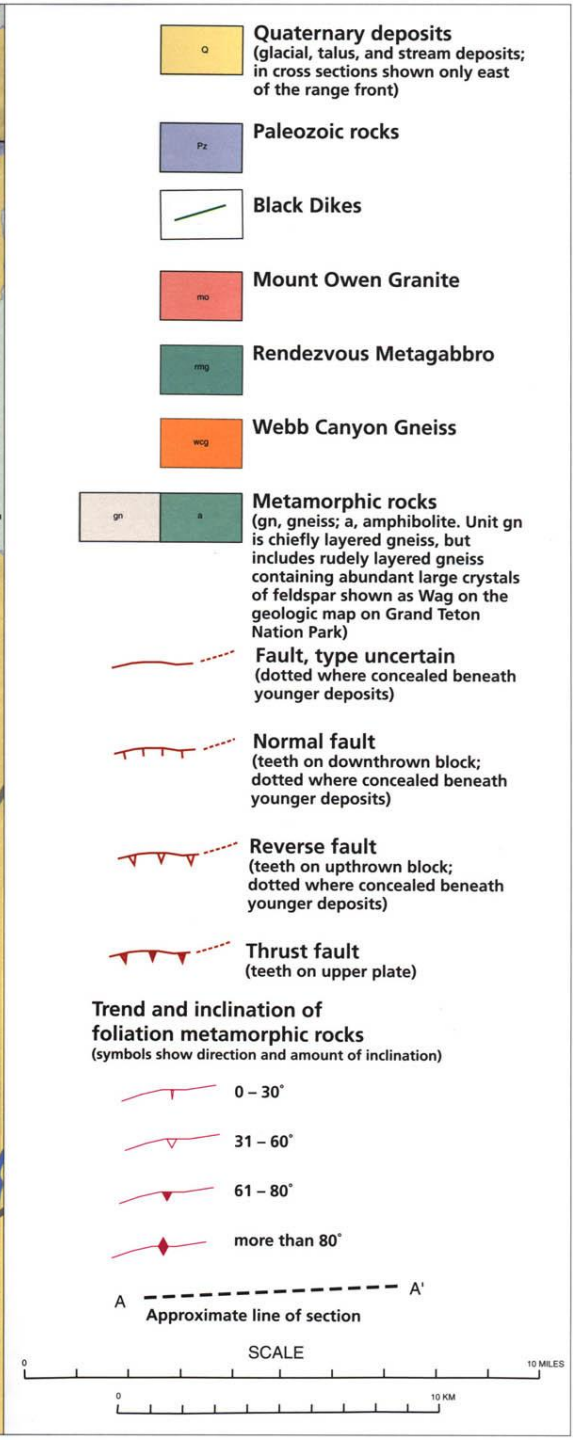
Proterozoic+

Granite Gneiss

Metagabbro

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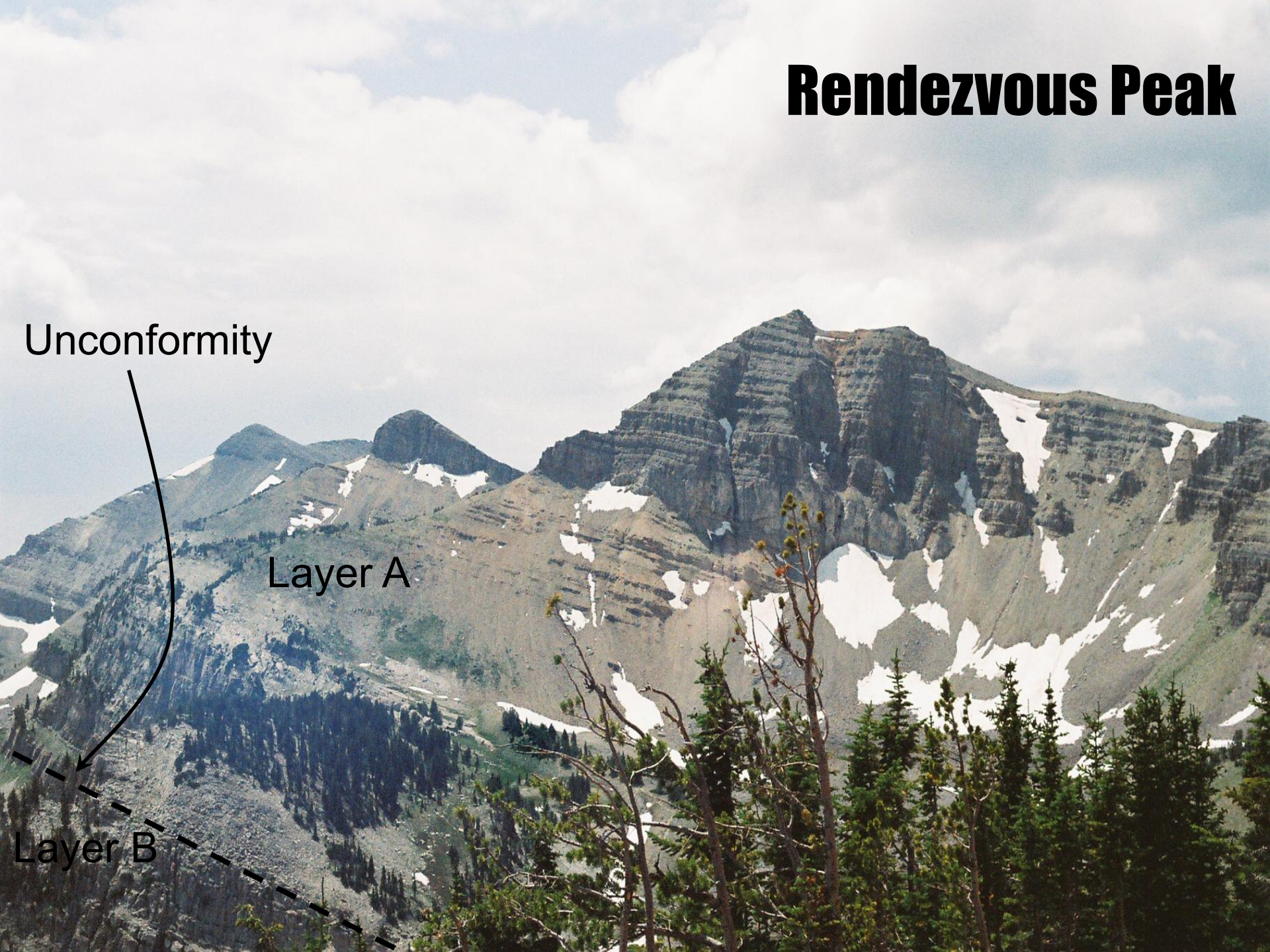
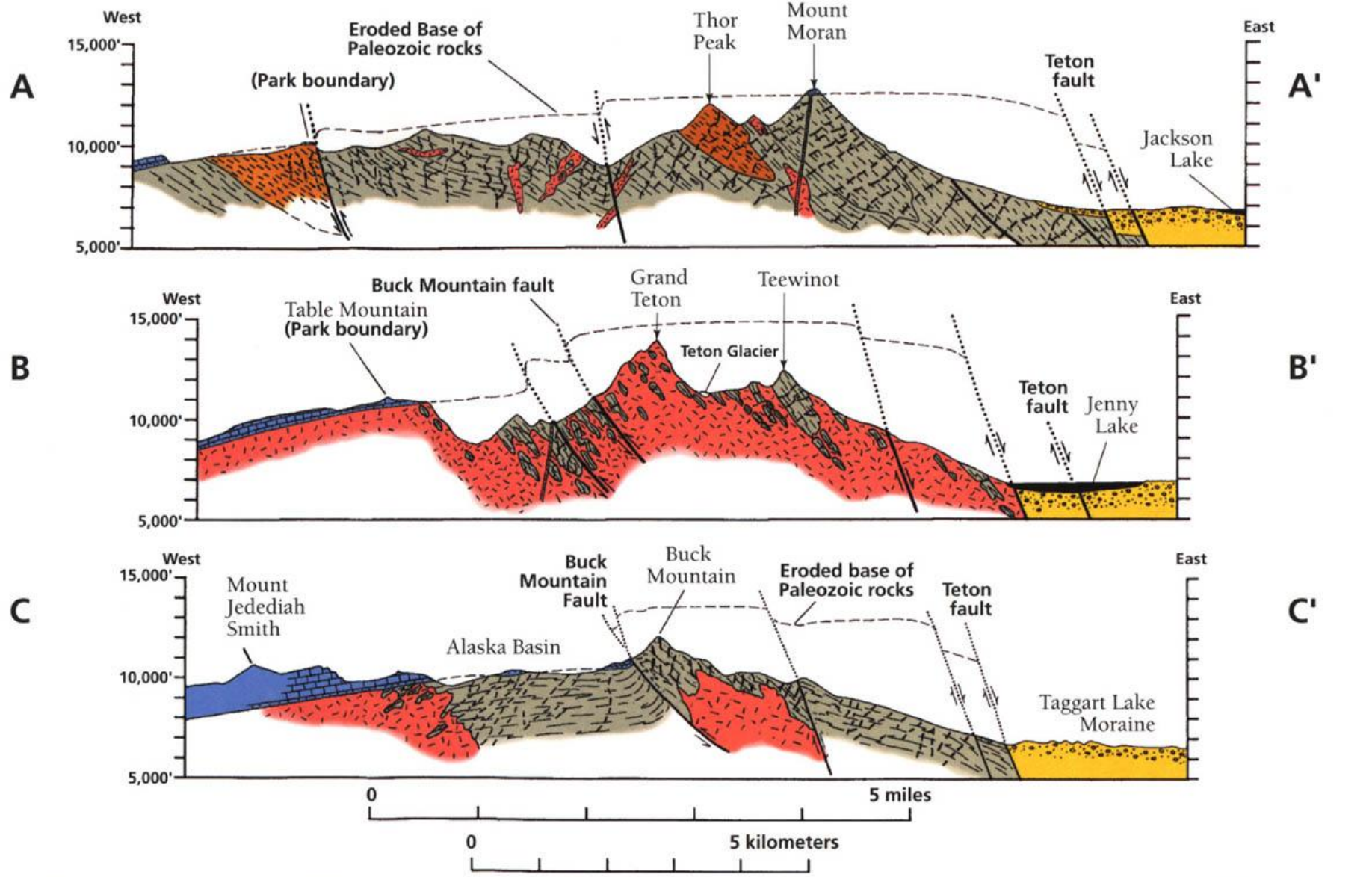
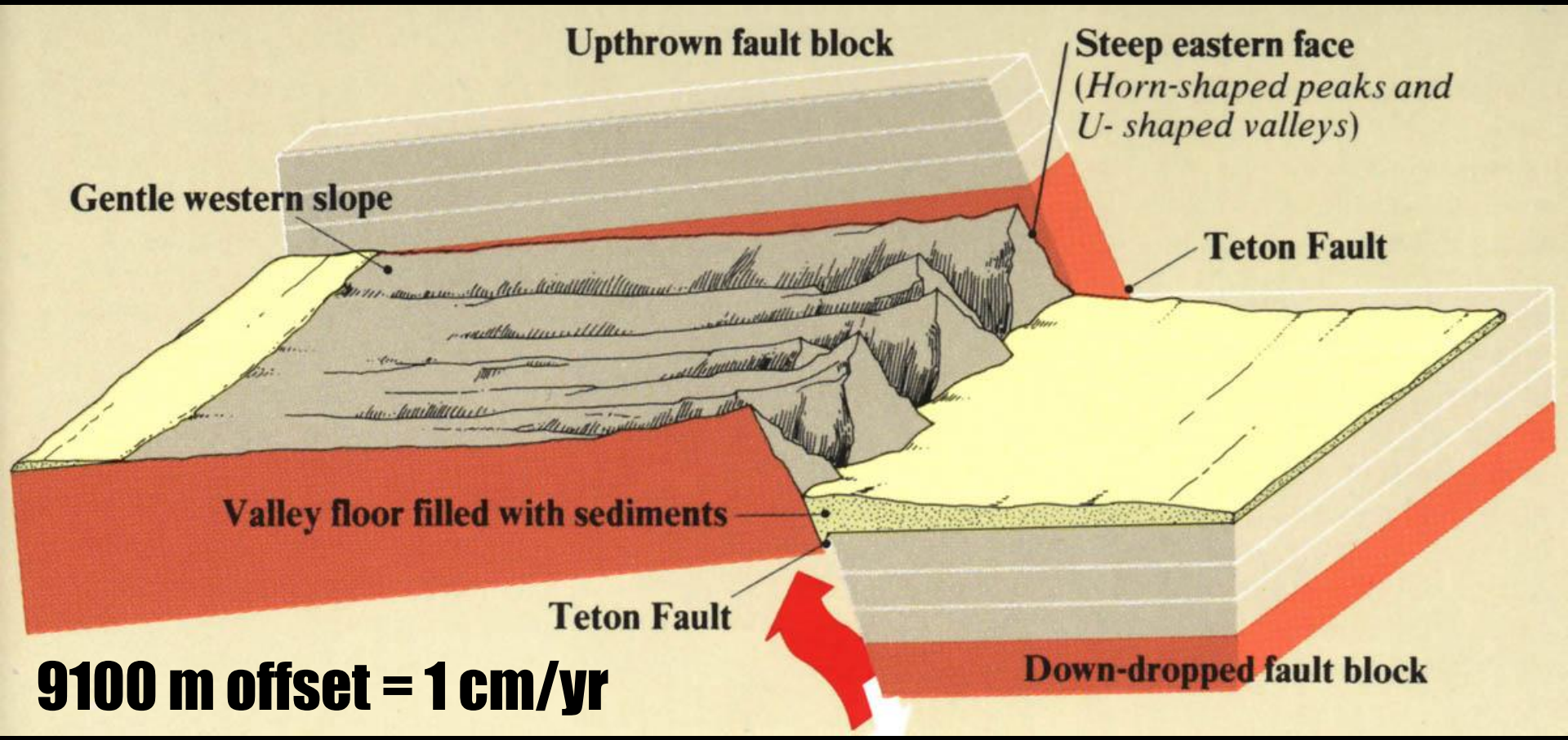
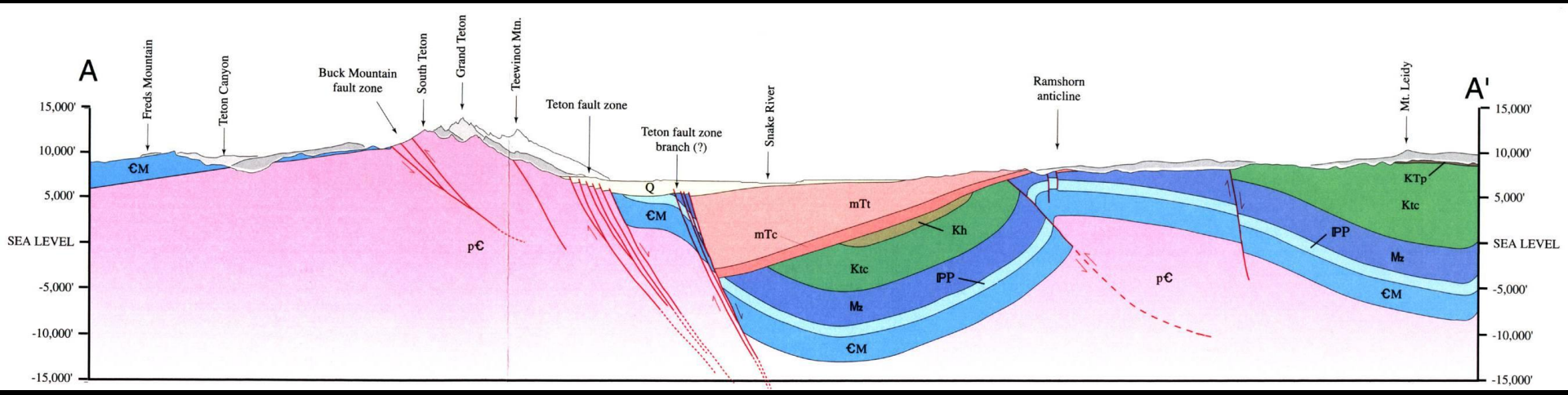
Rendezvous Peak




A
West
15,000'
10,000'
5,000'
Eroded Base of Paleozoic rocks
(Park boundary)
Thor Peak
Mount Moran
Teton fault
East
A'
Jackson Lake
B
West
15,000'
10,000'
5,000'
Buck Mountain fault
Table Mountain
(Park boundary)
Grand Teton
Teewinot
Teton Glacier
Teton fault
Jenny Lake
East
B'
C
West
15,000'
10,000'
5,000'
Mount Jedediah Smith
Alaska Basin
Buck Mountain Fault
Buck Mountain
Eroded base of Paleozoic rocks
Teton fault
East
C'
Taggart Lake Moraine
0
5 miles
0
5 kilometers
Glacial deposits
(shown only in Jackson Hole)
Paleozoic rocks
(sandstone, shale, limestone; dotted layer at base is Flathead Sandstone)
Diabase dikes
Mount Owen Quartz Monzonite
(heavy dashed lines in wall rocks show trends of related aplite and pegmatite dikes)
Granite gneiss
(Webb Canyon Gneiss and related rocks; fine dashed lines show trends of foliation)
Layered gneiss
(fine dashed lines show trends at foliation and layering)

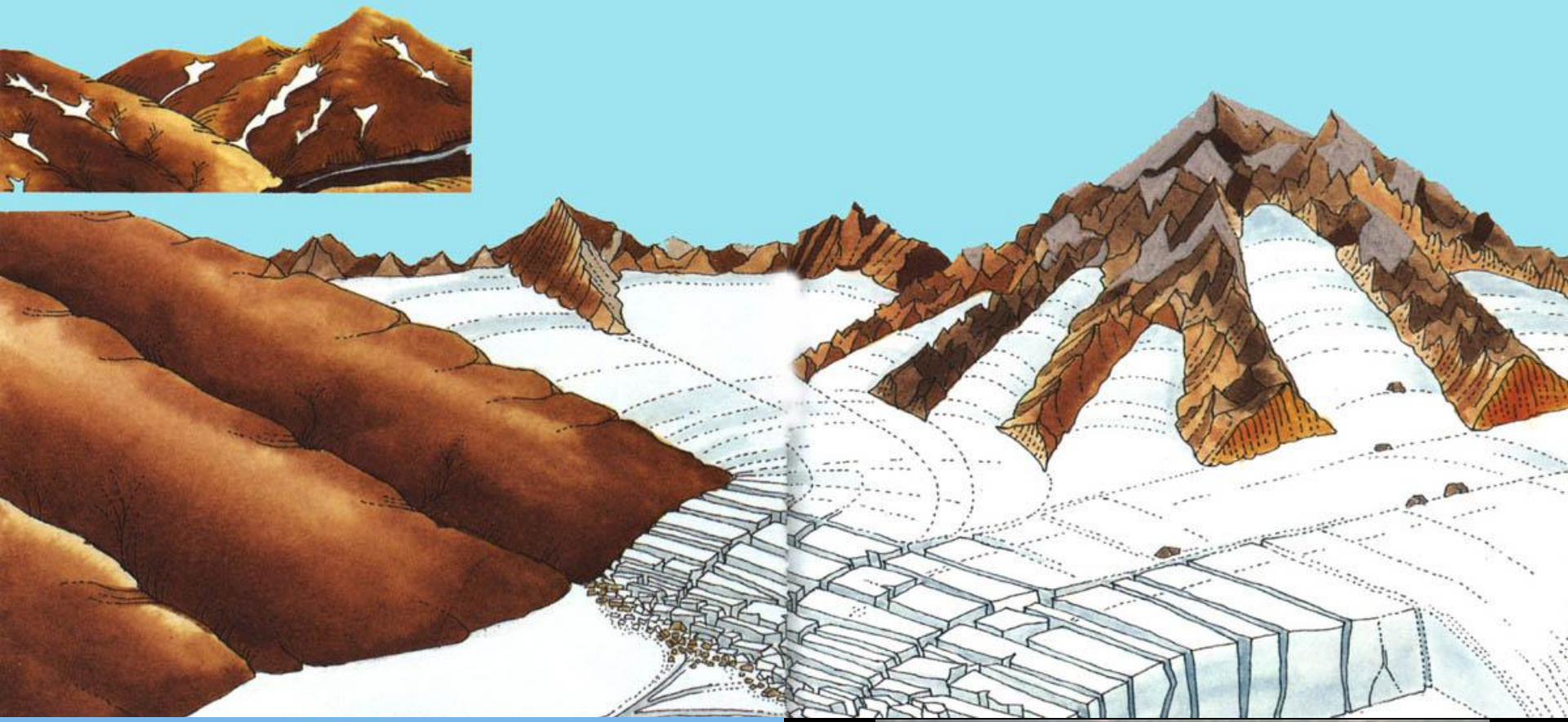


9100 m offset = 1 cm/yr



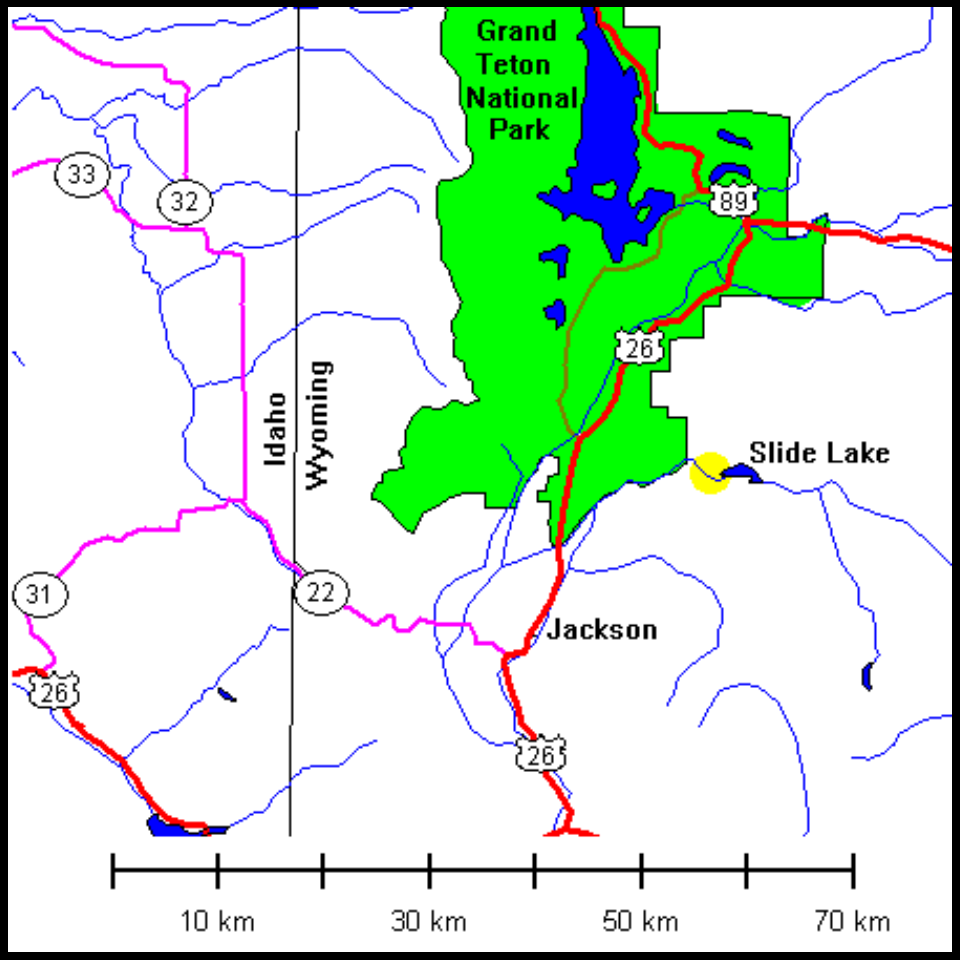

Grand Teton

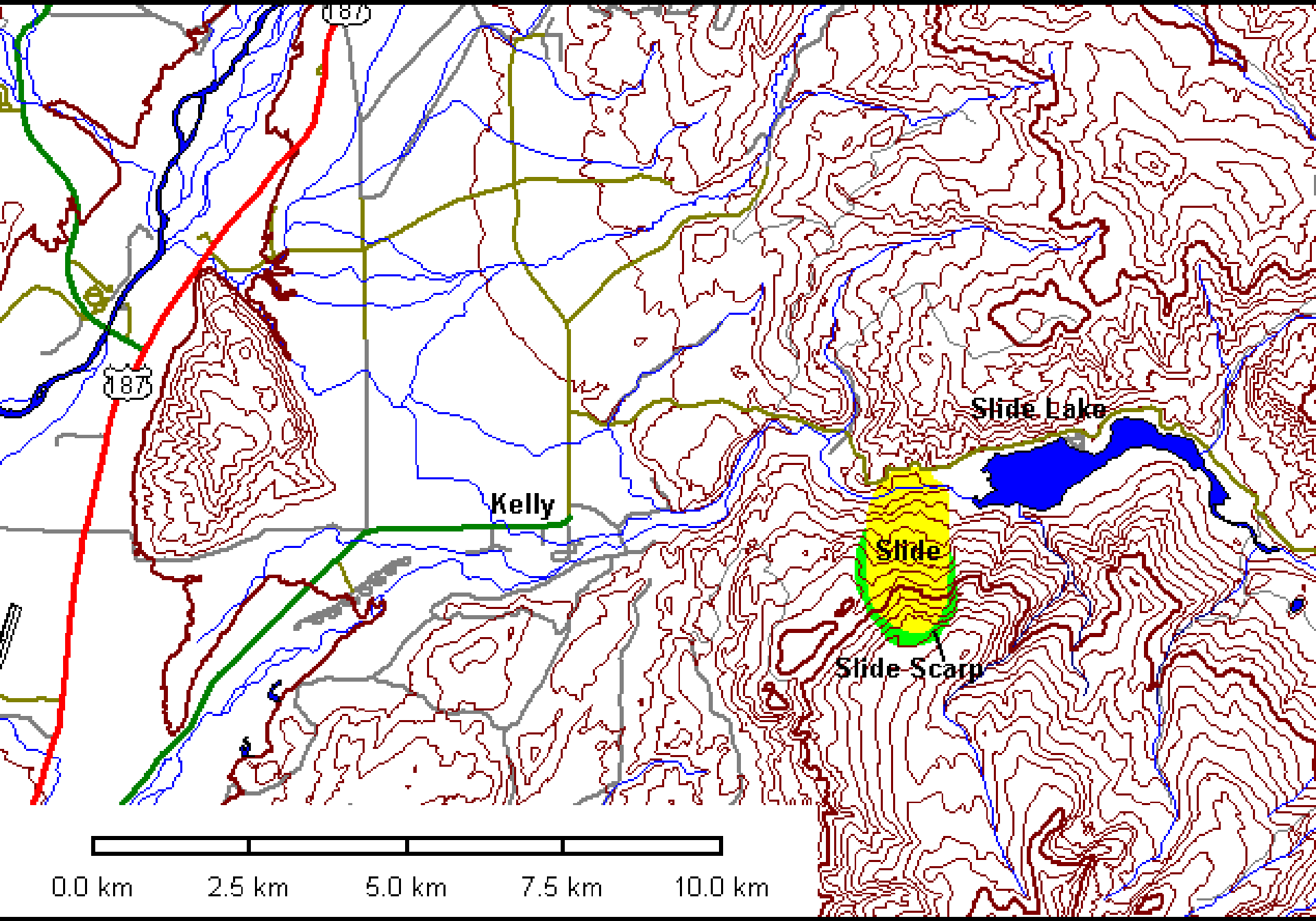

Mt. Moran

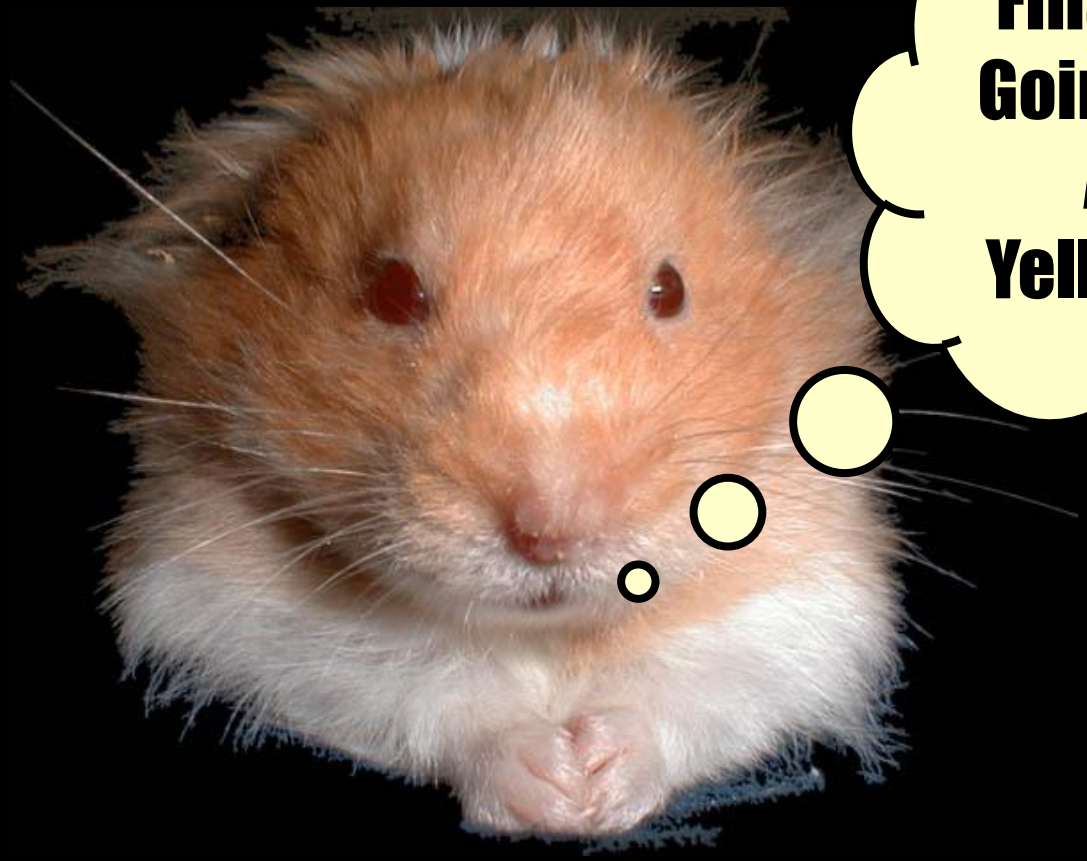


Gros Ventre Slide

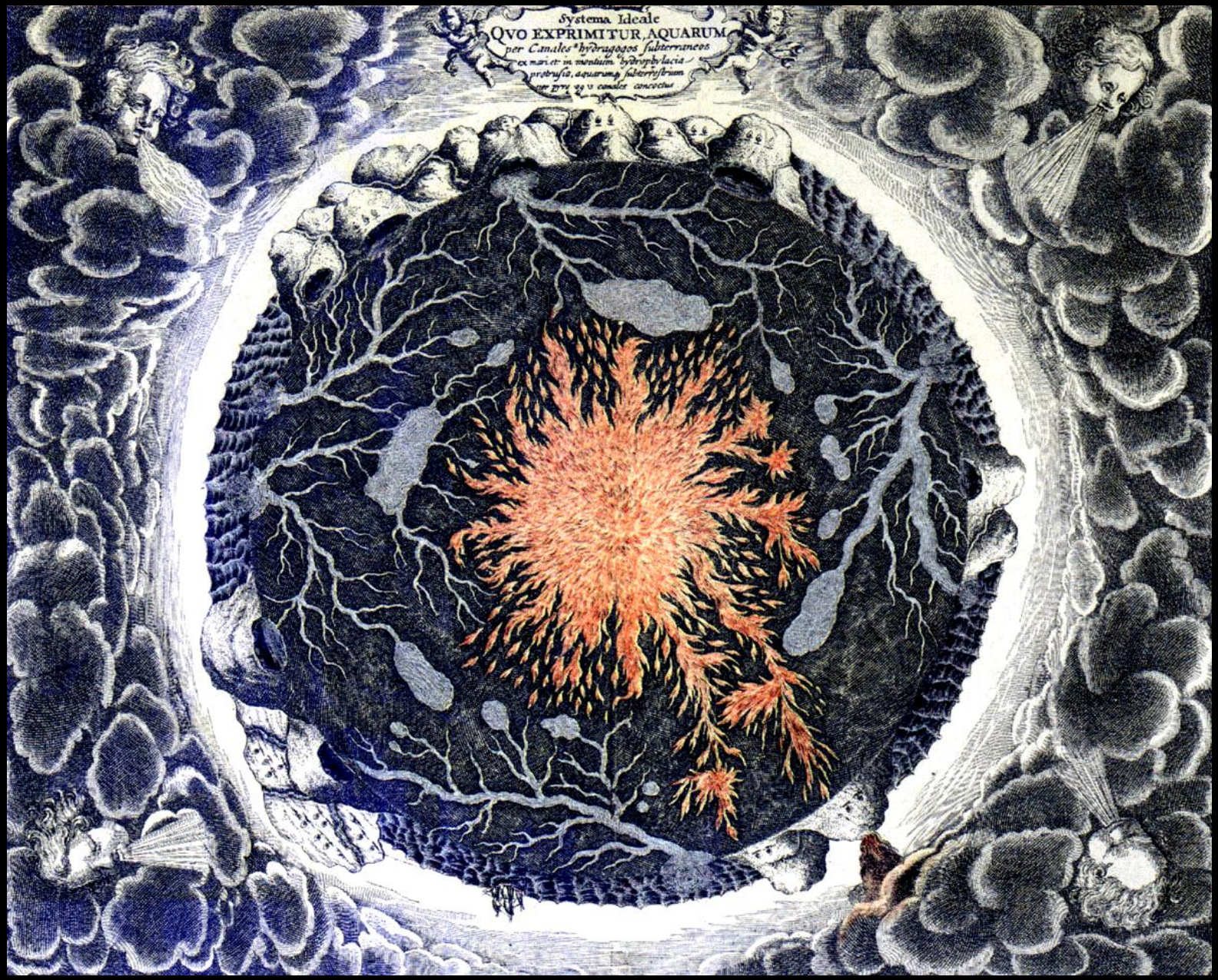
June 1925 Quake
10 Cubic Miles of Rock
1927 Failure of Slide Lake




187
187
Kelly
Slide Lake
Slide
Slide Scarp
0.0 km
2.5 km
5.0 km
7.5 km
10.0 km

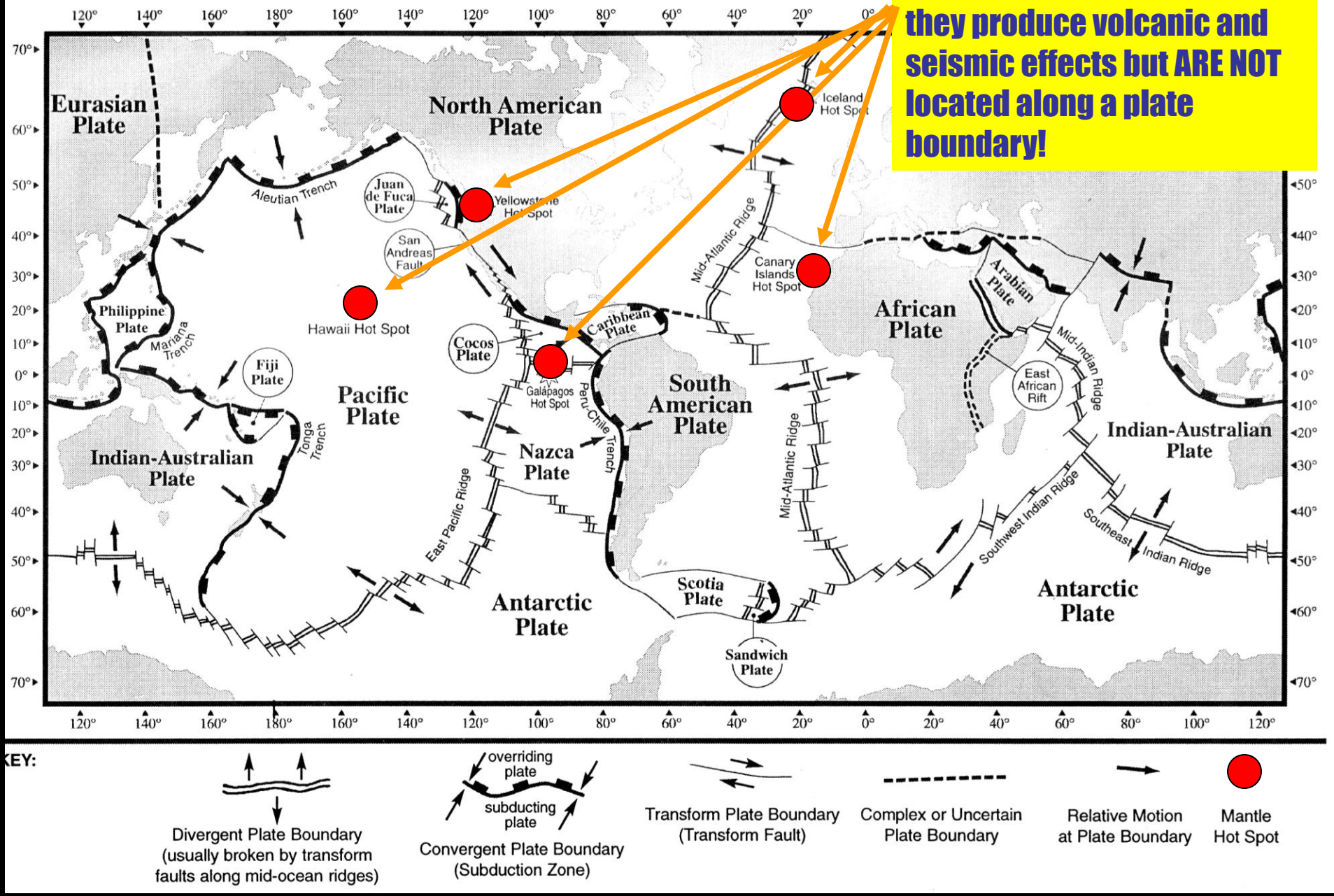

Finally, He's Going to Talk About Yellowstone

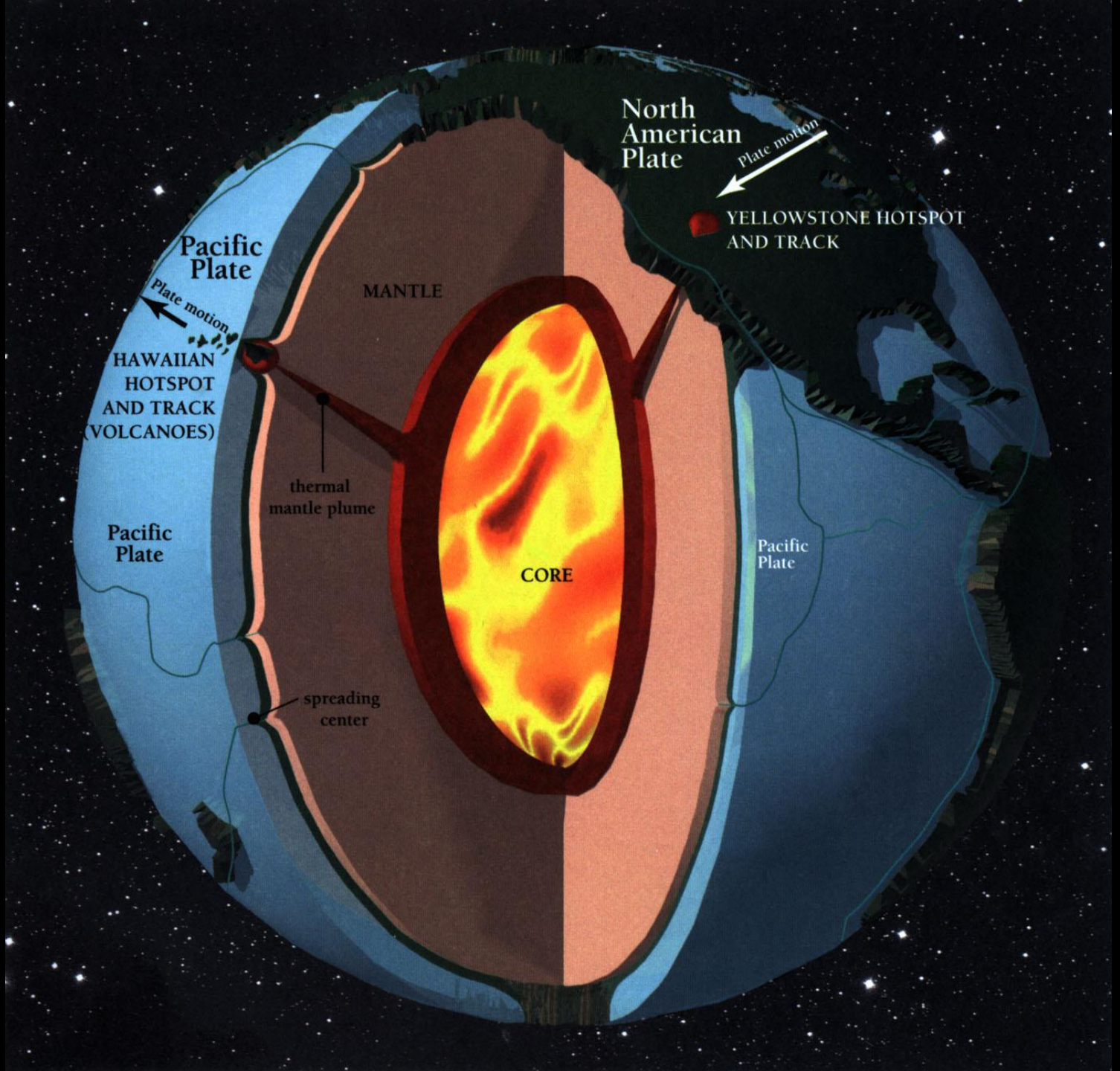
Hot Spot Field Trips



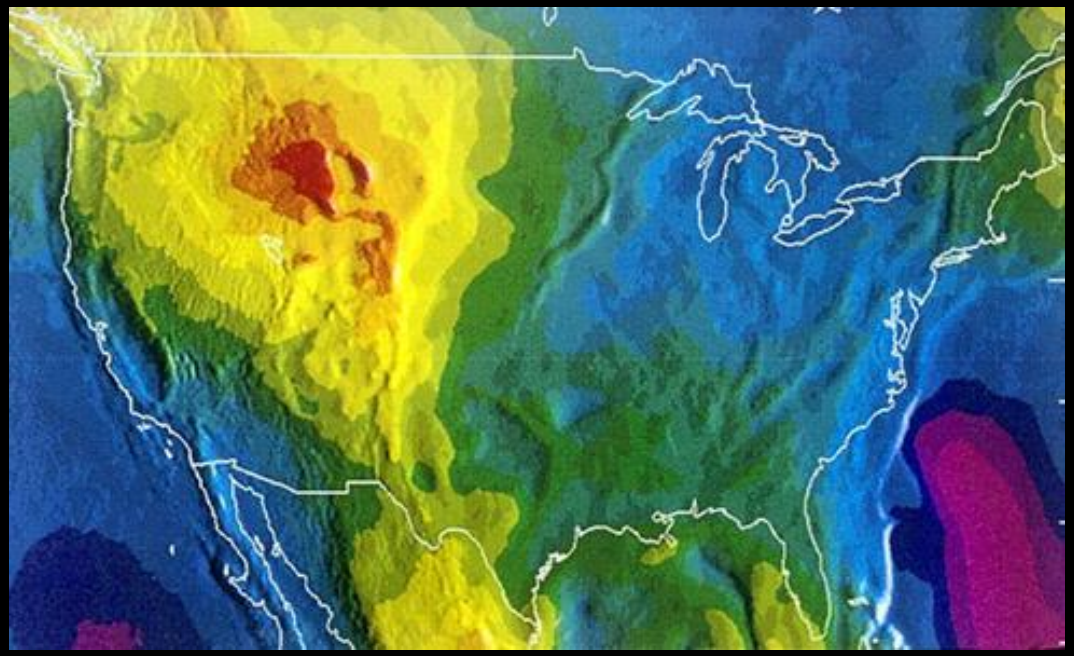
Kircher (1600^{s}) – Mundus Subteraneos

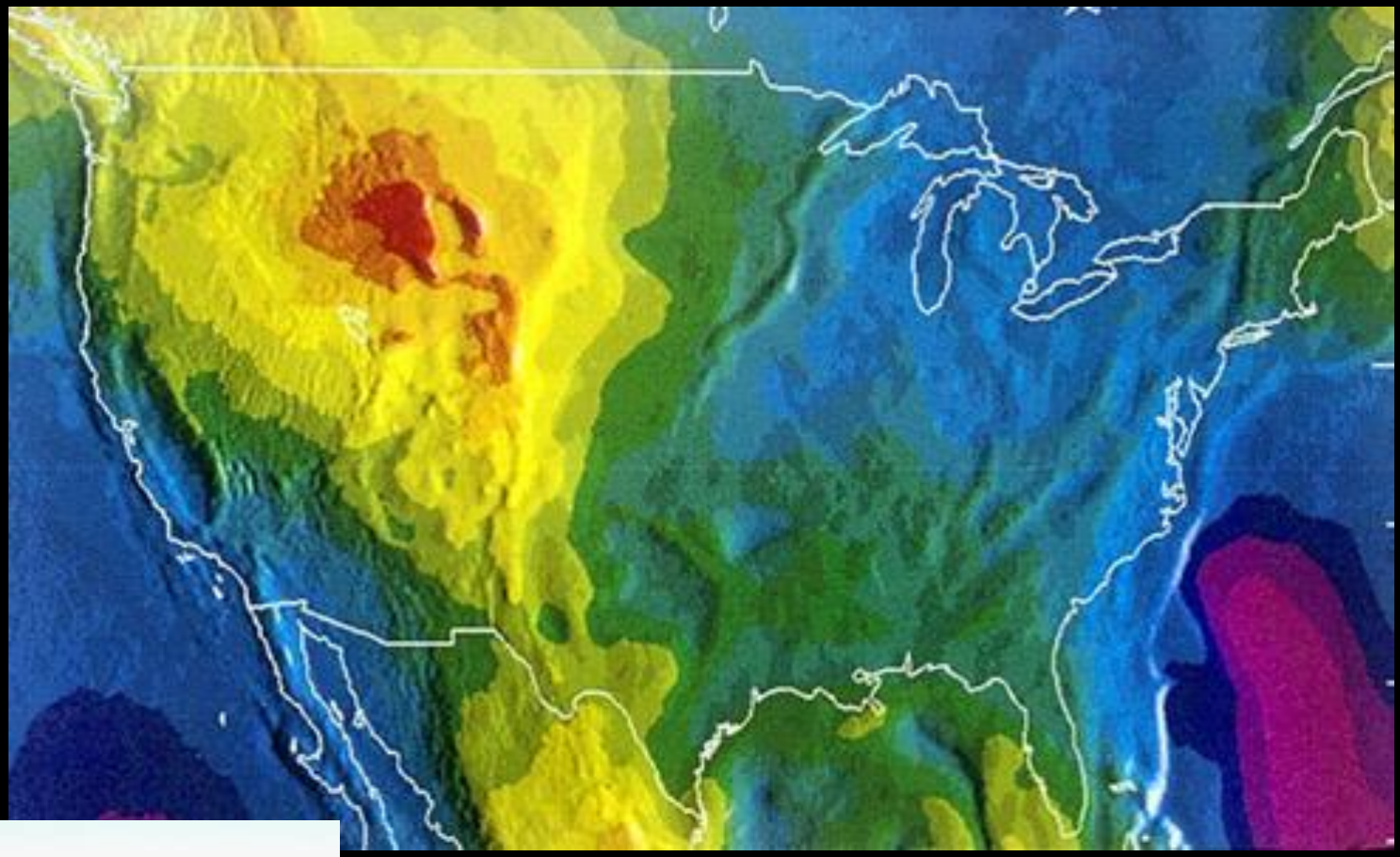
Hot Spots are unique as they produce volcanic and seismic effects but ARE NOT located along a plate boundary!



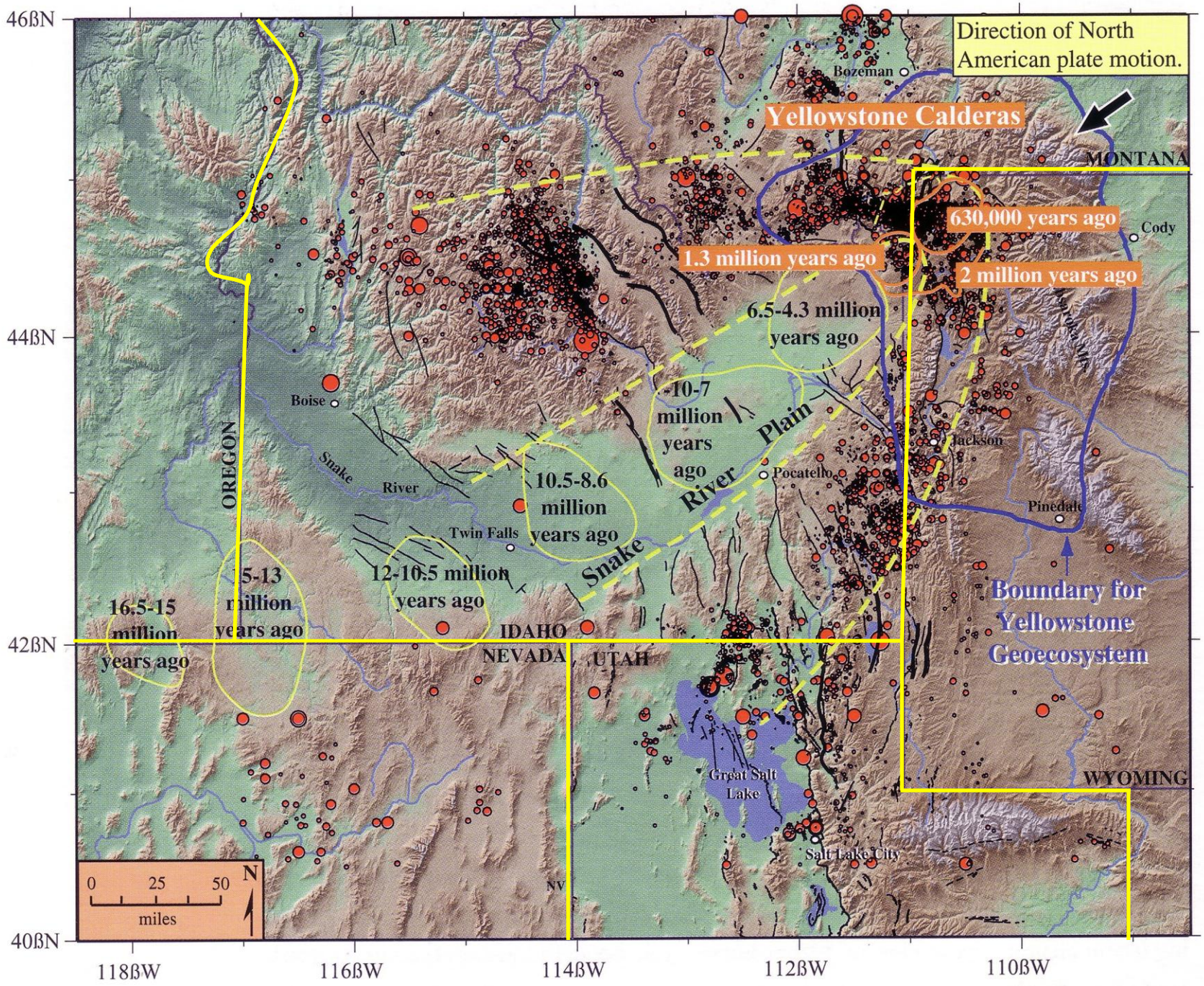

North American Plate
Plate motion
YELLOWSTONE HOTSPOT AND TRACK
Pacific Plate
Plate motion
HAWAIIAN HOTSPOT AND TRACK (VOLCANOES)
MANTLE
thermal mantle plume
CORE
Pacific Plate
Pacific Plate
spreading center

- High Heat Flow
- Gravity 30% lower than normal = hot rock + water
- Seismic waves slower than expected
- Yellowstone Lake rising on south end
- Satellite methods show caldera heaving

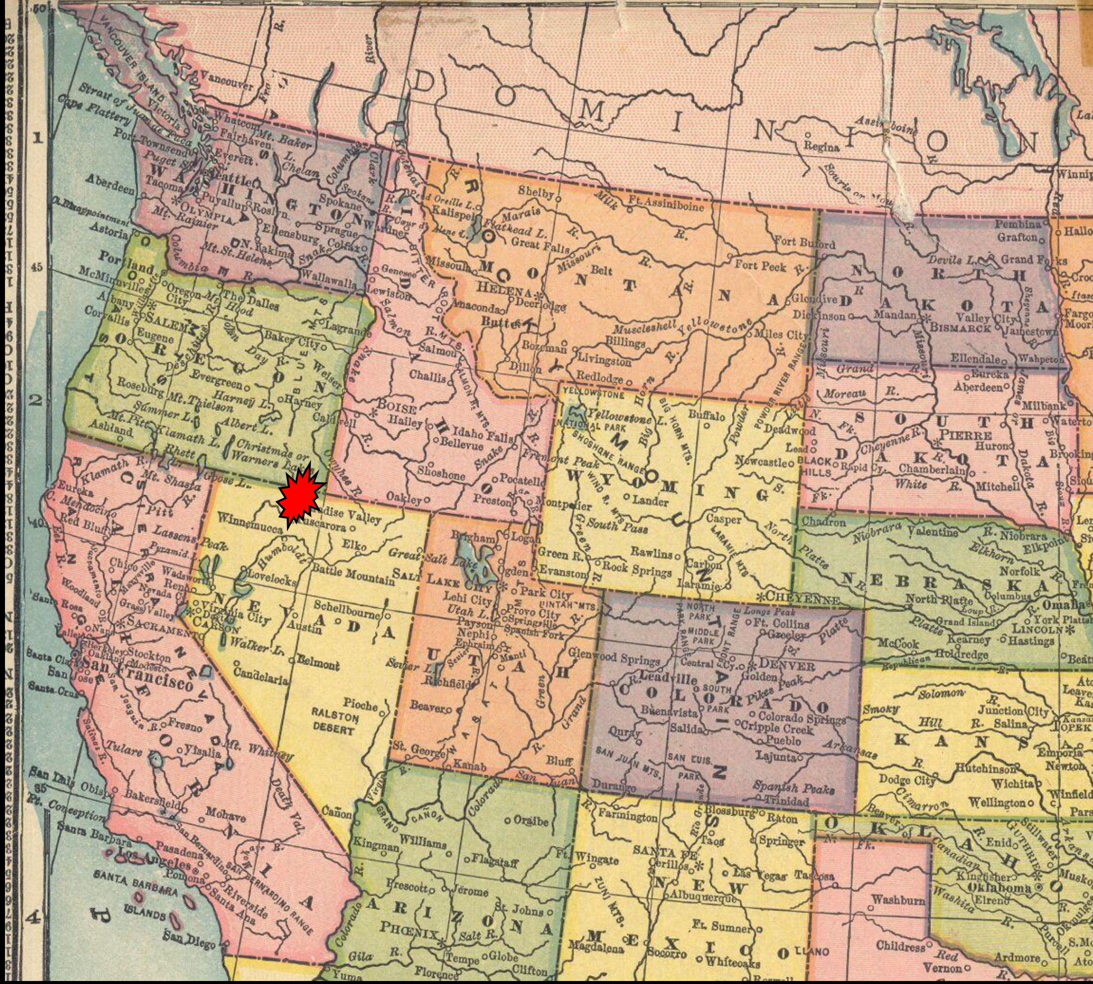




Yellowstone Hot Spot Track

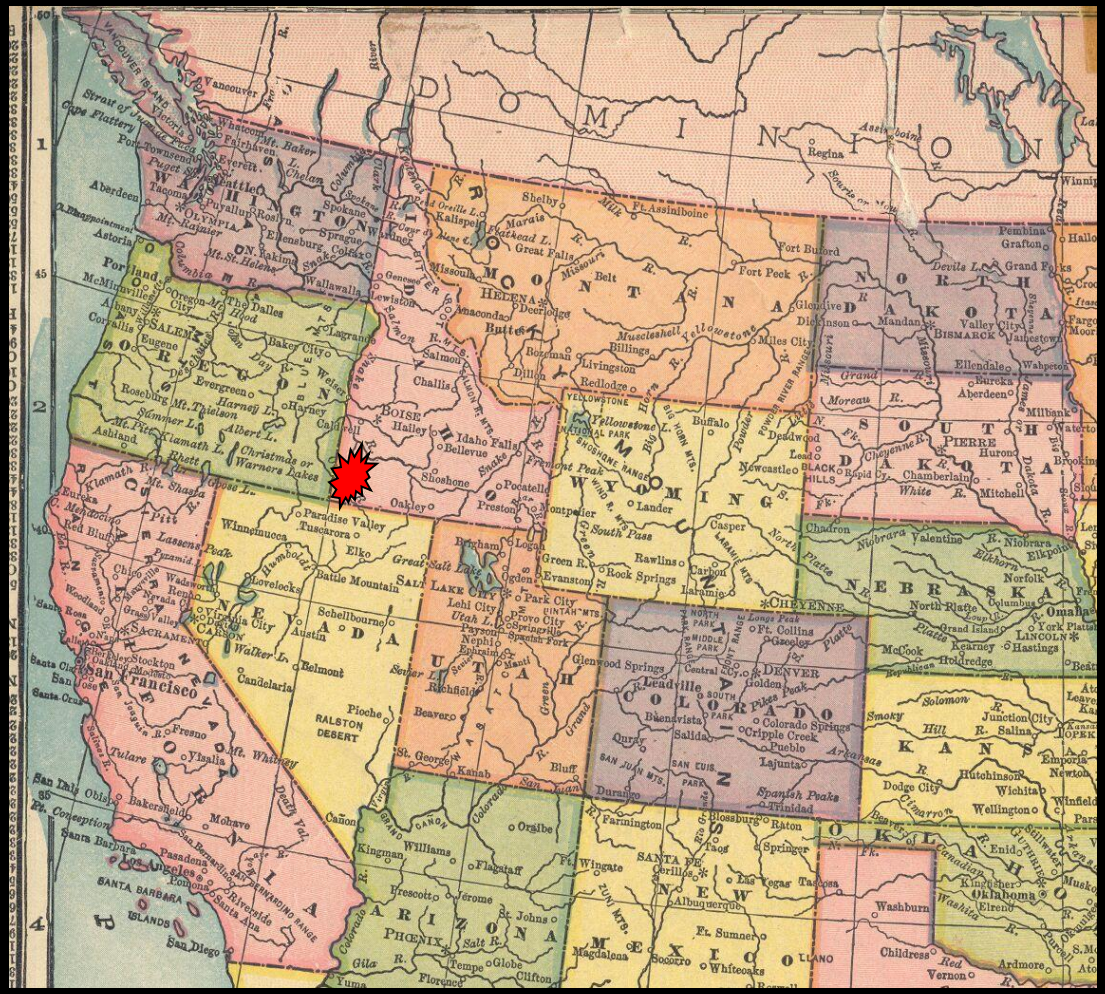

Direction of North American plate motion.
Yellowstone Calderas
630,000 years ago
1.3 million years ago
2 million years ago
6.5-4.3 million years ago
10-7 million years ago
10.5-8.6 million years ago
12-10.5 million years ago
16.5-15 million years ago
Snake River Plain
Boundary for Yellowstone Geoecosystem
Bozeman
Cody
Jackson
Pocatello
Pinedale
Boise
Twin Falls
Snake River
OREGON
IDAHO
NEVADA
UTAH
MONTANA
WYOMING
Great Salt Lake
Salt Lake City
NV
0 25 50
miles
N
46ßN
44ßN
42ßN
40ßN
118ßW
116ßW
114ßW
112ßW
110ßW

Hot Spot Tracks Movement of the North American Plate Over the Yellowstone Hot Spot

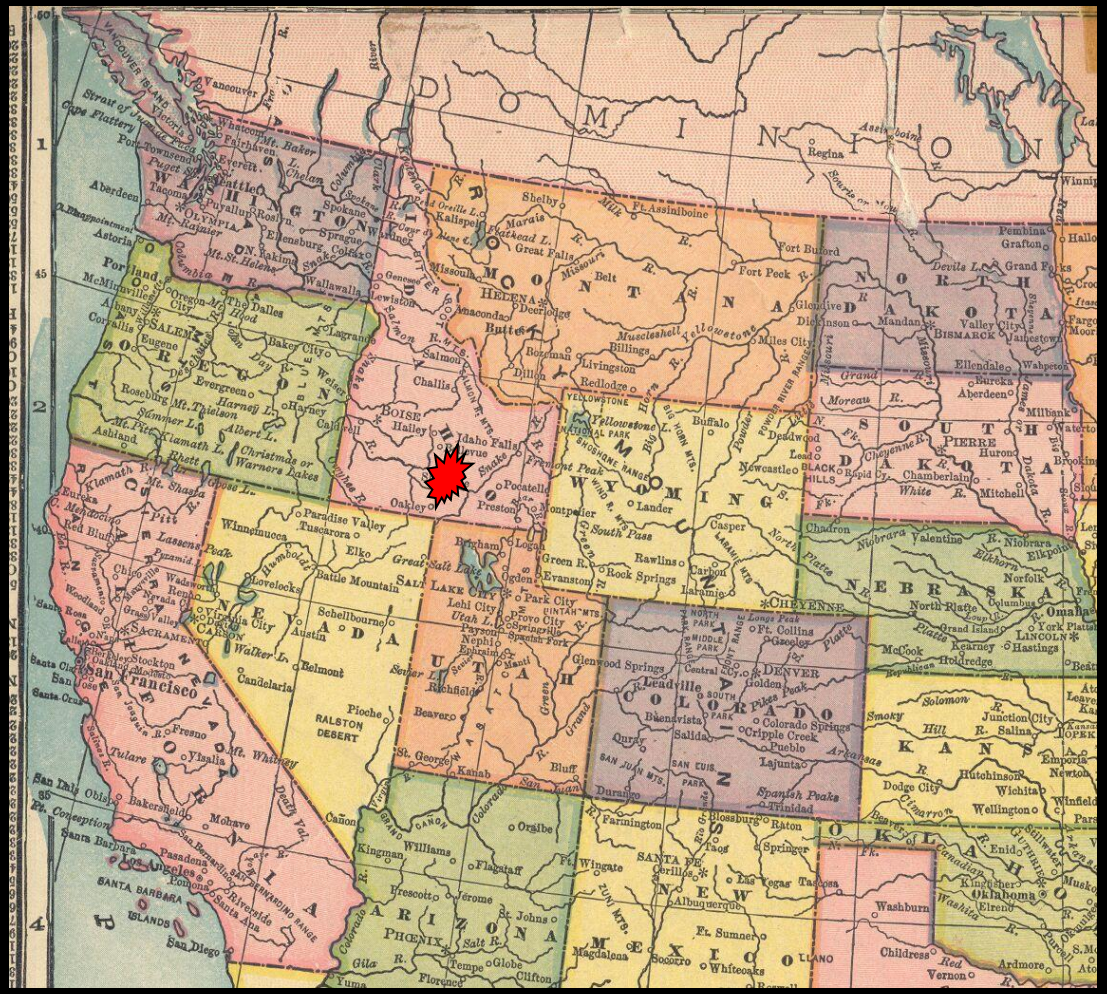


16.5 - 15 Ma - Miocene

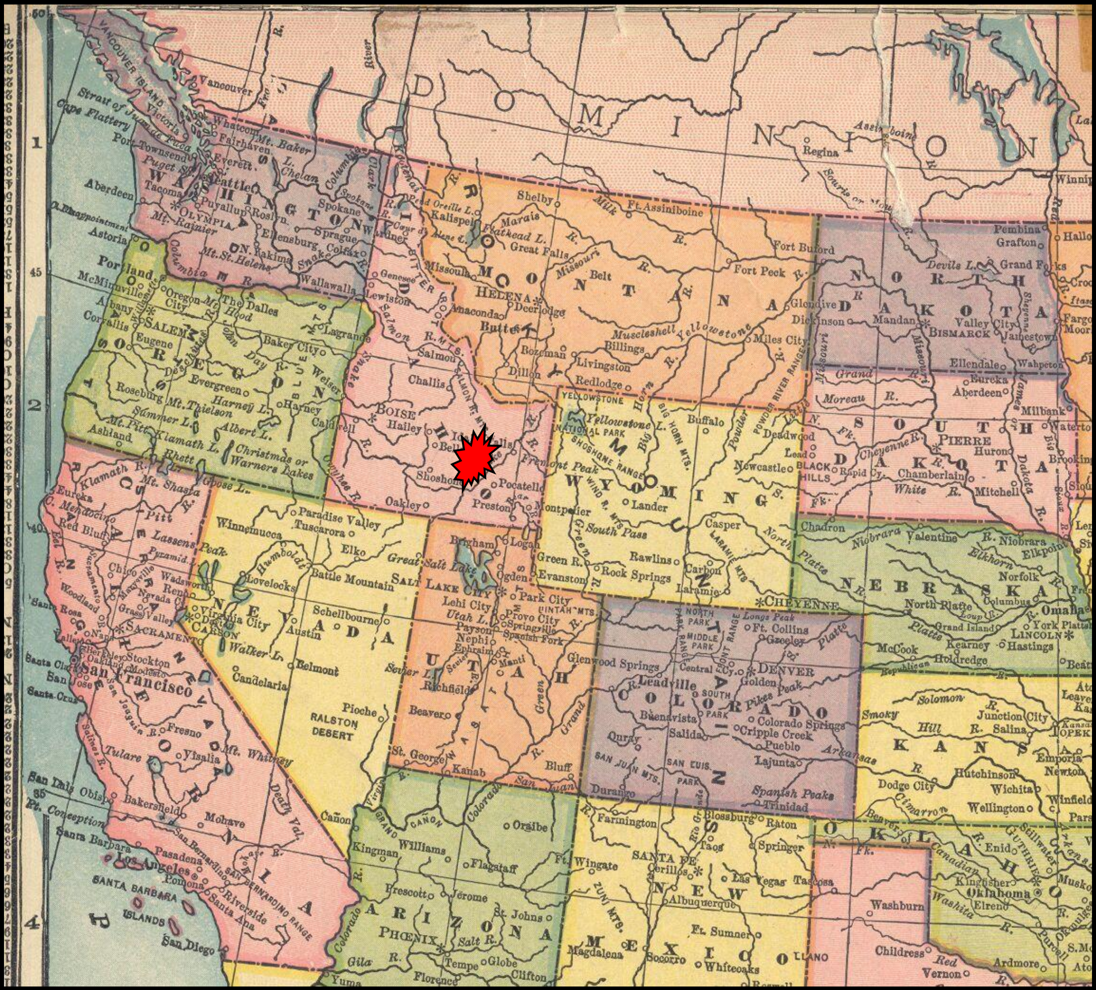
Courtesy: Andy Orgonik



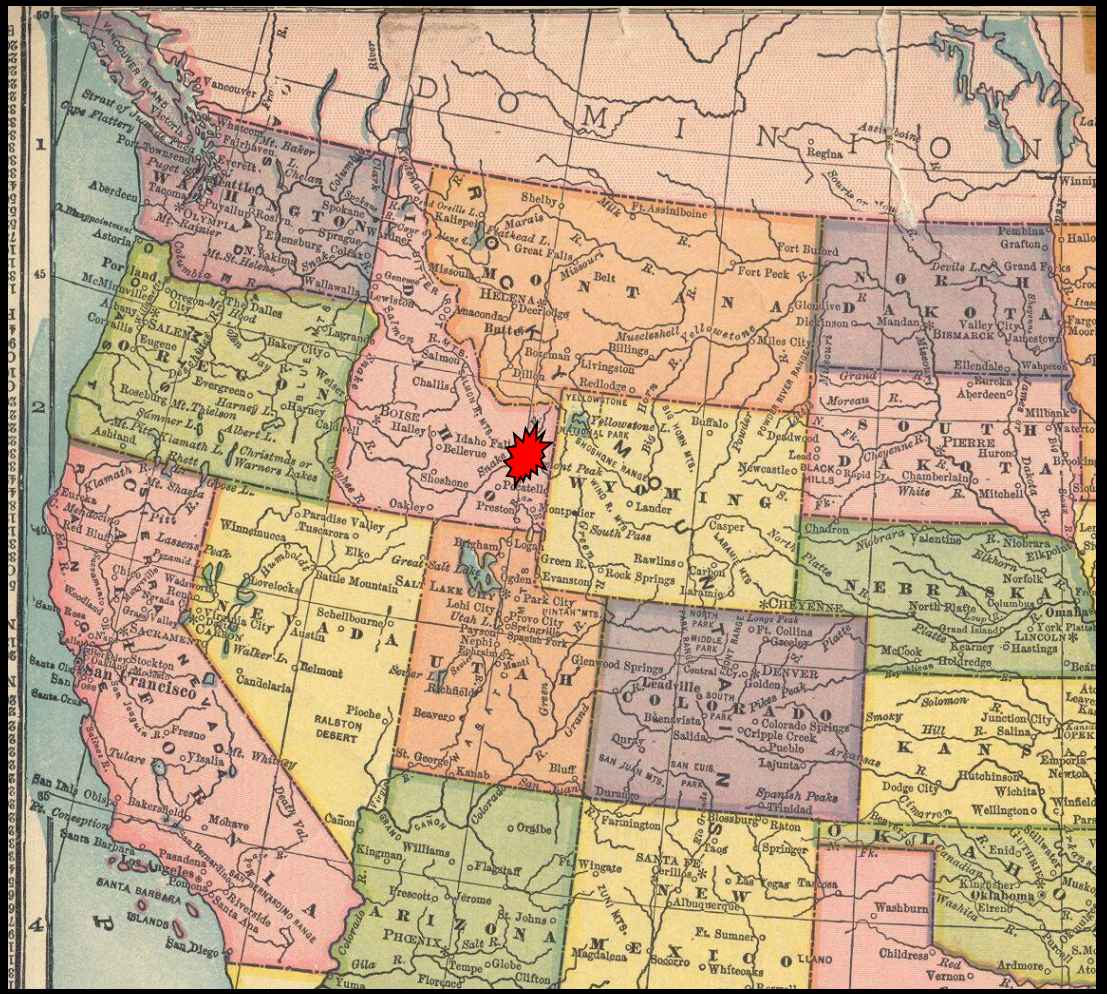
15 – 13 Ma - Miocene



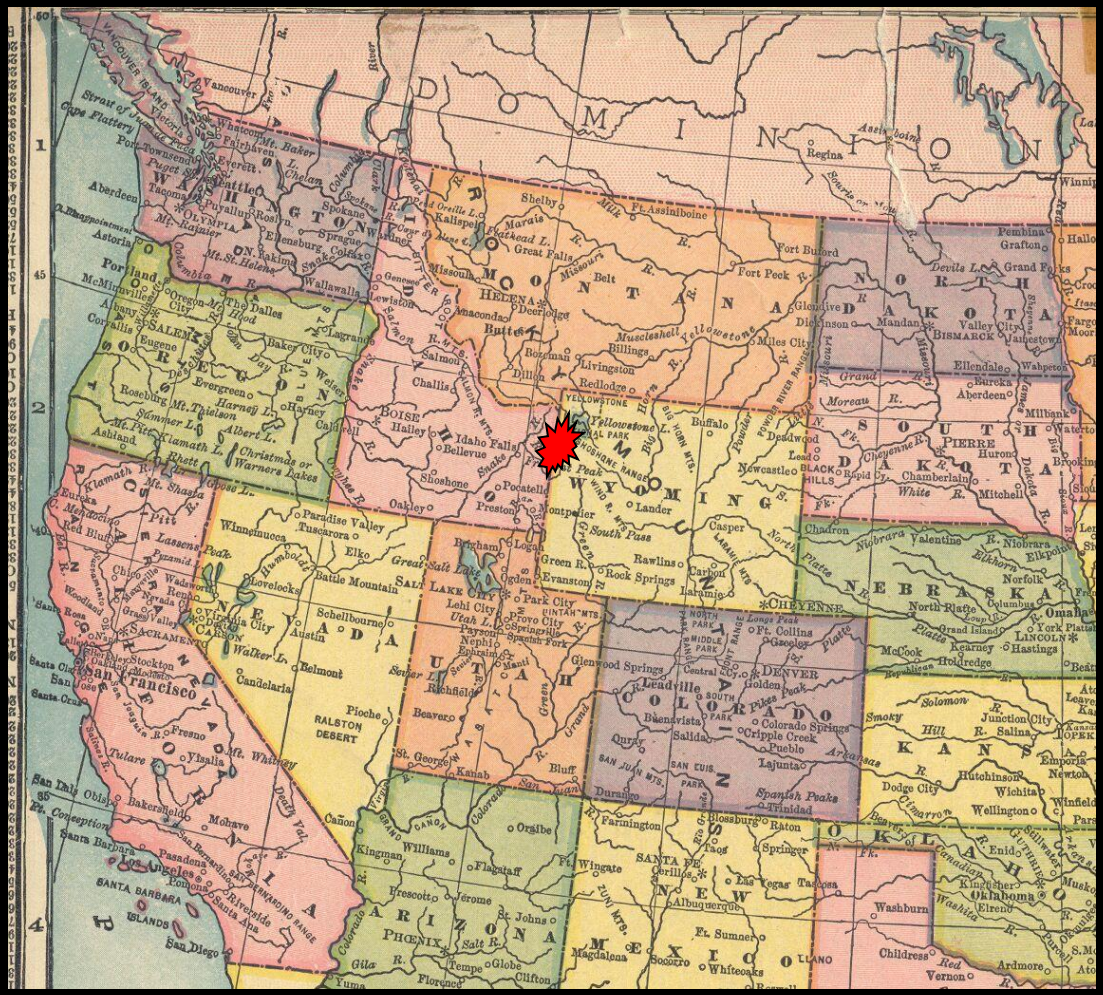
10.5 – 8.6 Ma - Miocene



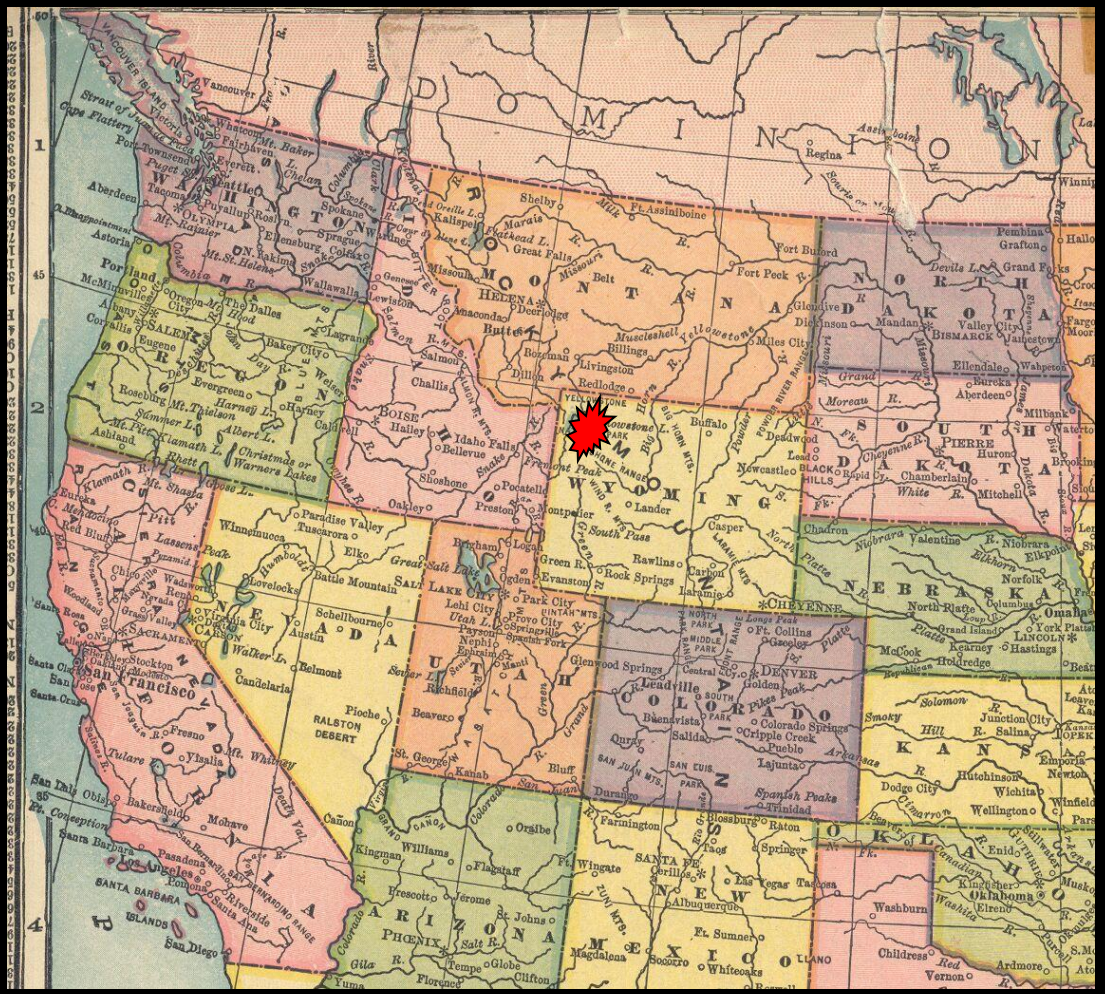
10 – 7 Ma - Miocene



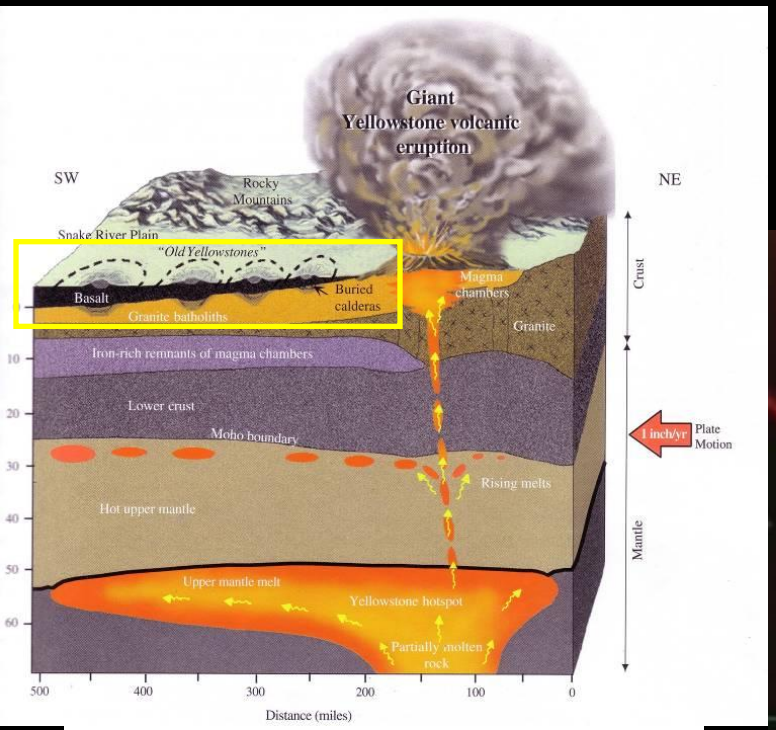
6.5 – 4.3 Ma – Miocene/Pliocene

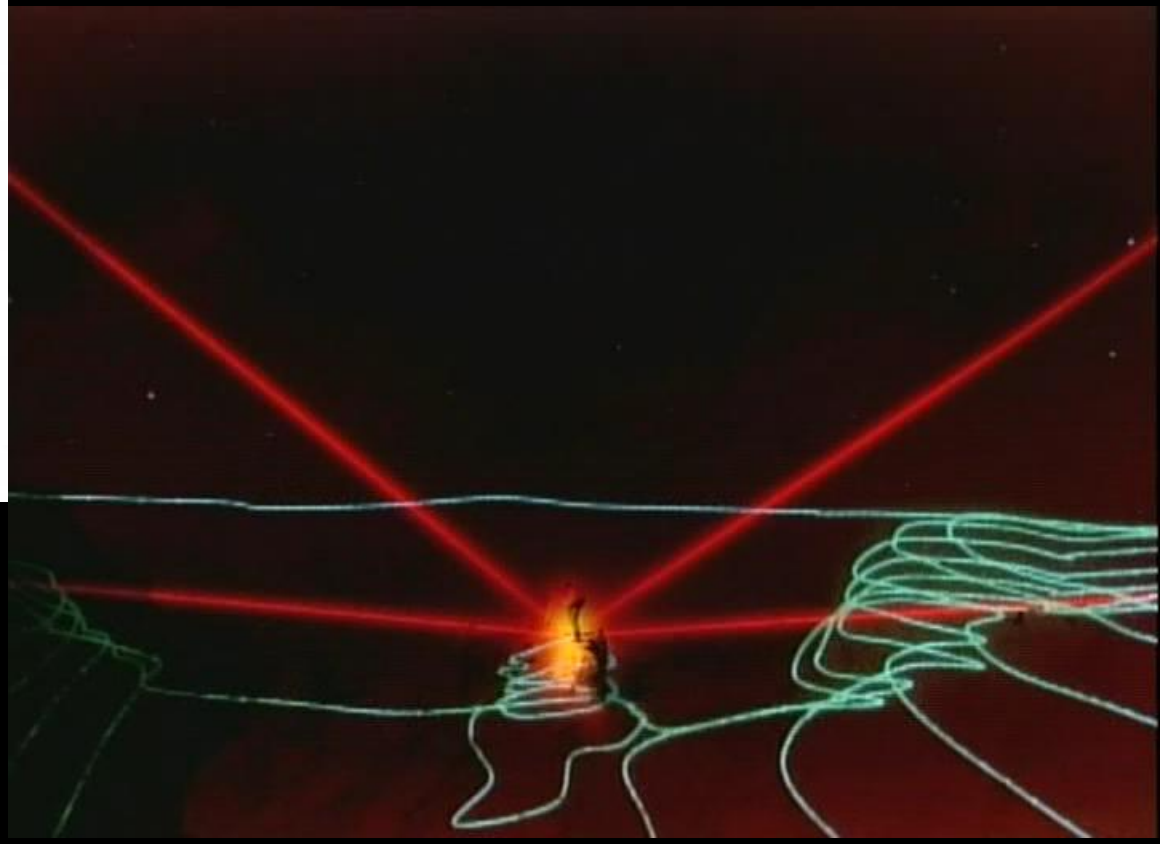


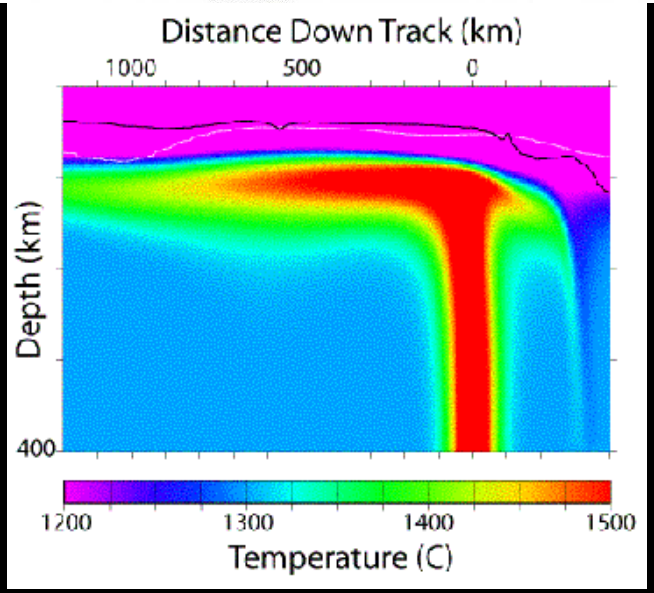
2 – 1.3 Ma – Pliocene/Pleistocene

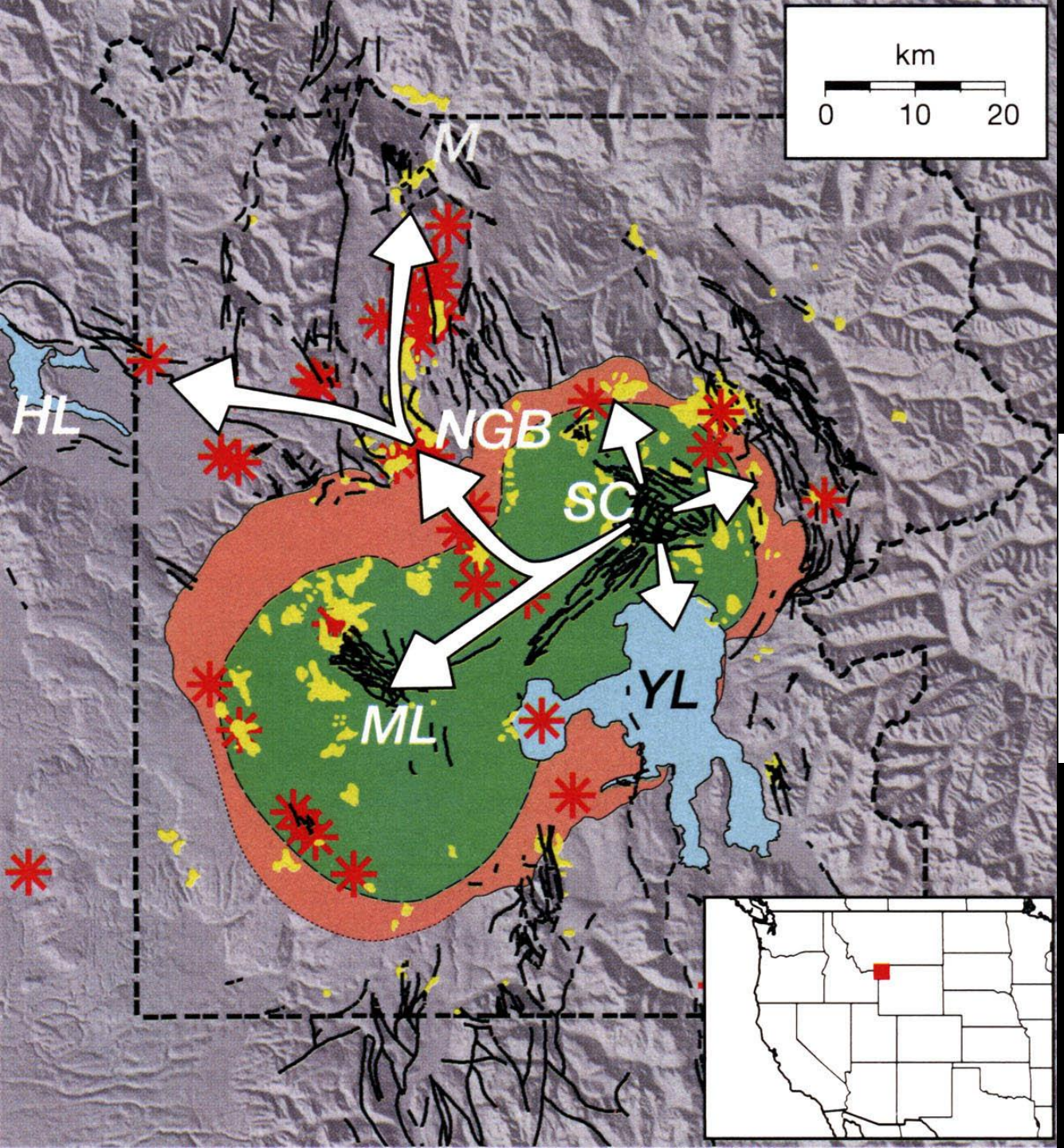


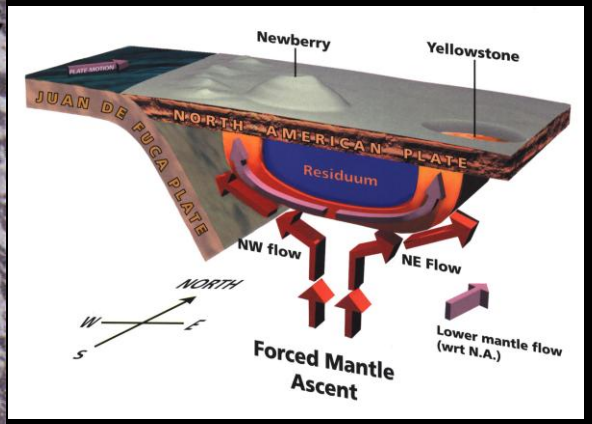
630,000 years ago to present

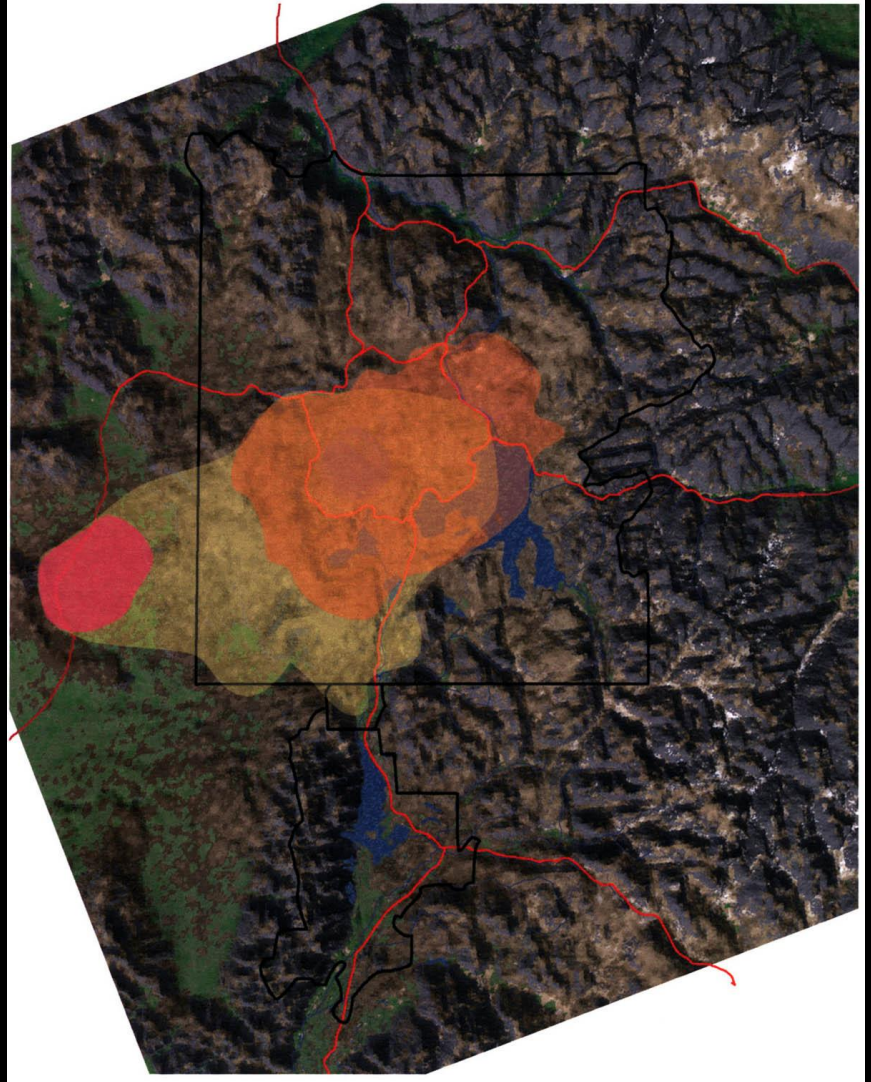

Giant
Yellowstone volcanic
eruption
SW
NE
Rocky
Mountains
Snake River Plain
"Old Yellowstones"
Basalt
Buried
calderas
Granite batholiths
Magma
chambers
Granite
Crust
Iron-rich remnants of magma chambers
Lower crust
Moho boundary
1 inch/yr
Plate
Motion
Rising melts
Hot upper mantle
Mantle
Upper mantle melt
Yellowstone hotspot
Partially molten
rock
10
20
30
40
50
60
500
400
300
200
100
0
Distance (miles)




Distance Down Track (km)
1000
500
0
Depth (km)
400
1200
1300
1400
1500
Temperature (C)


km
0
10
20
M
HL
NGB
SC
YL
ML


Newberry
Yellowstone
JUAN DE FUCA PLATE
NORTH AMERICAN PLATE
Residuum
NW flow
NE Flow
NORTH
W
E
S
Forced Mantle Ascent
Lower mantle flow (wrt N.A.)



2.1 million years ago. Caldera of the Huckleberry Ridge Tuff.

1.3 million years ago. Caldera of the Mesa Falls Tuff.

0.65 million years ago. Caldera of the Lava Creek Tuff.

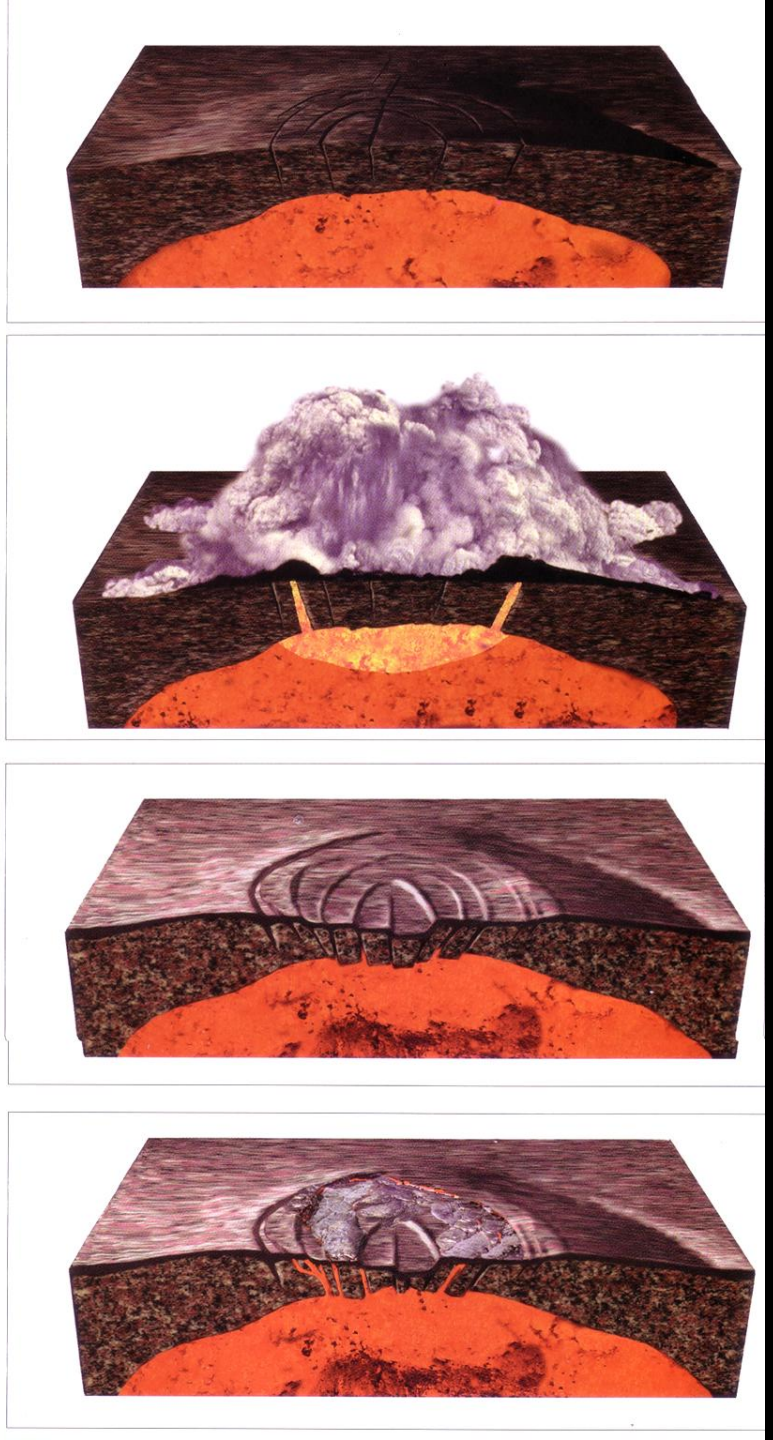
Three Eruptive Events

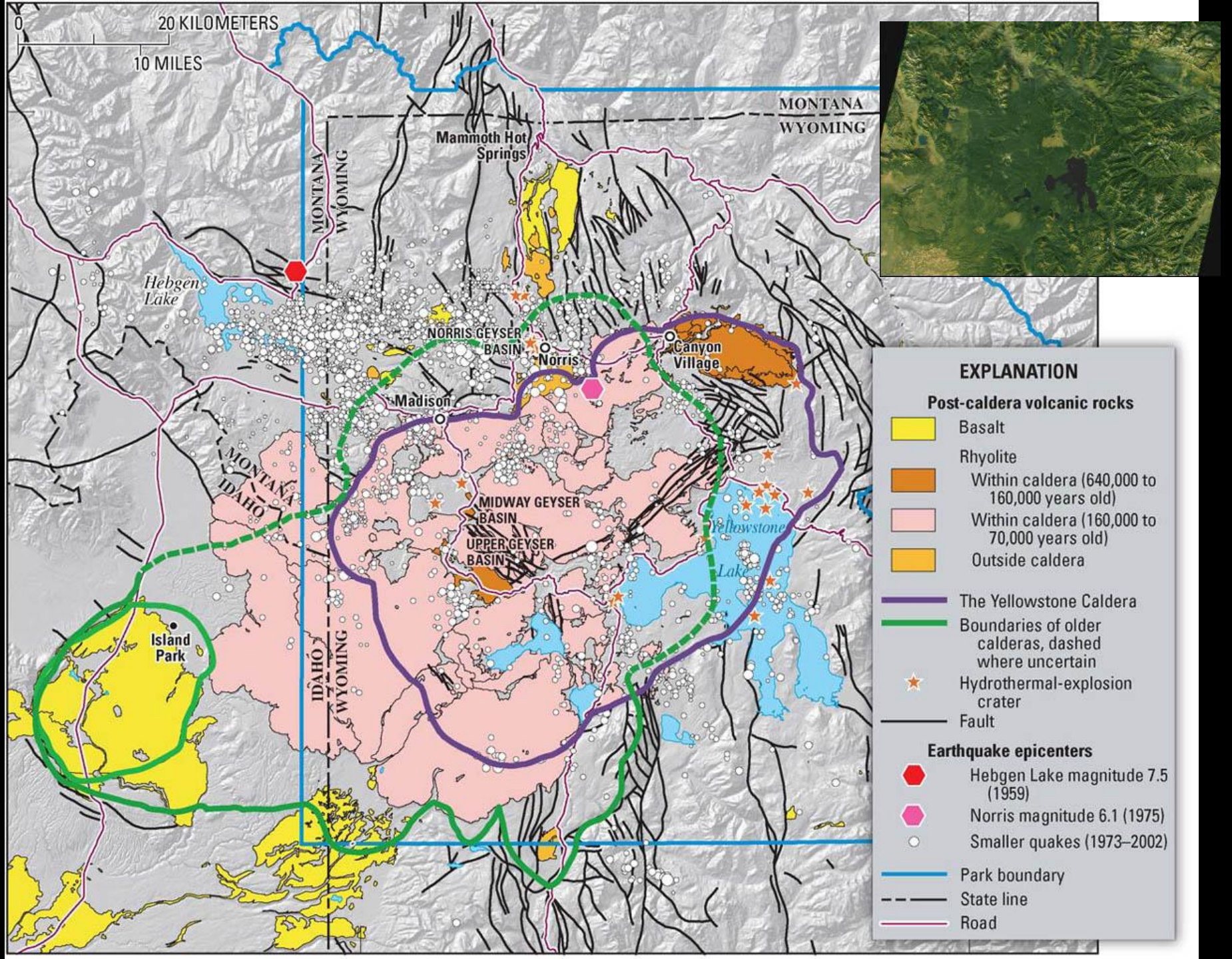
640 Ka – Lava Creek Caldera

1.3 Ma – Mesa Falls Caldera

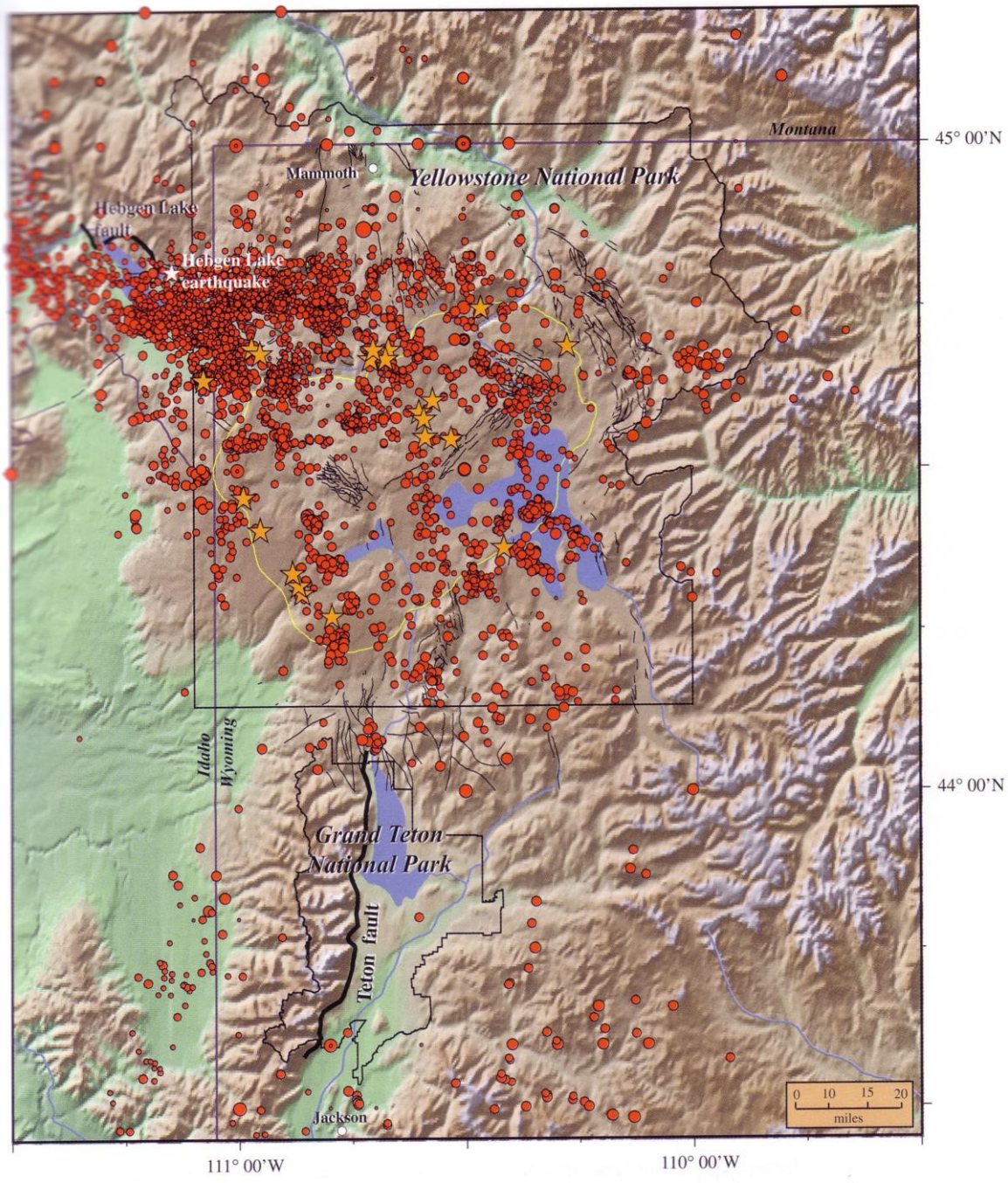
2.1 Ma – Huckleberry Ridge Caldera

How Does an Eruption Cause a Caldera to Form?




0
20 KILOMETERS
10 MILES
MONTANA
WYOMING
Mammoth Hot Springs
MONTANA
WYOMING
Hebgen Lake
NORRIS GEYSER BASIN
Norris
Canyon Village
Madison
MONTANA
IDAHO
MIDWAY GEYSER BASIN
UPPER GEYSER BASIN
Yellowstone Lake
Island Park
IDAHO
WYOMING
EXPLANATION
Post-caldera volcanic rocks
Basalt
Rhyolite
Within caldera (640,000 to 160,000 years old)
Within caldera (160,000 to 70,000 years old)
Outside caldera
The Yellowstone Caldera
Boundaries of older calderas, dashed where uncertain
Hydrothermal-explosion crater
Fault
Earthquake epicenters
Hebgen Lake magnitude 7.5 (1959)
Norris magnitude 6.1 (1975)
Smaller quakes (1973–2002)
Park boundary
State line
Road

Earthquakes of the Yellowstone-Teton region from 1973-1996



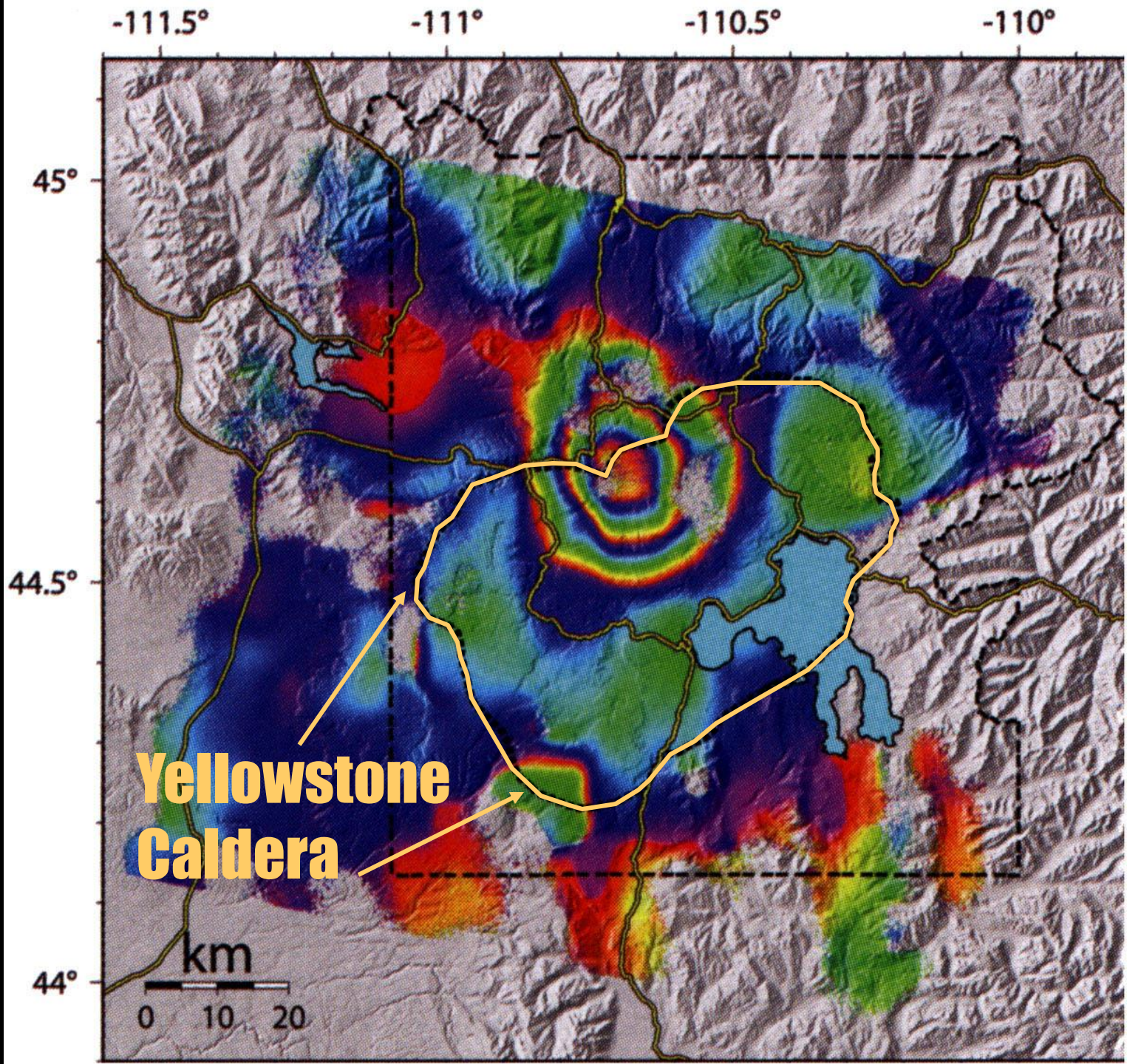
- Numerous Faults Cause Periodic Seismic Activity
- Earthquakes Vary in Magnitude but Most < M 5

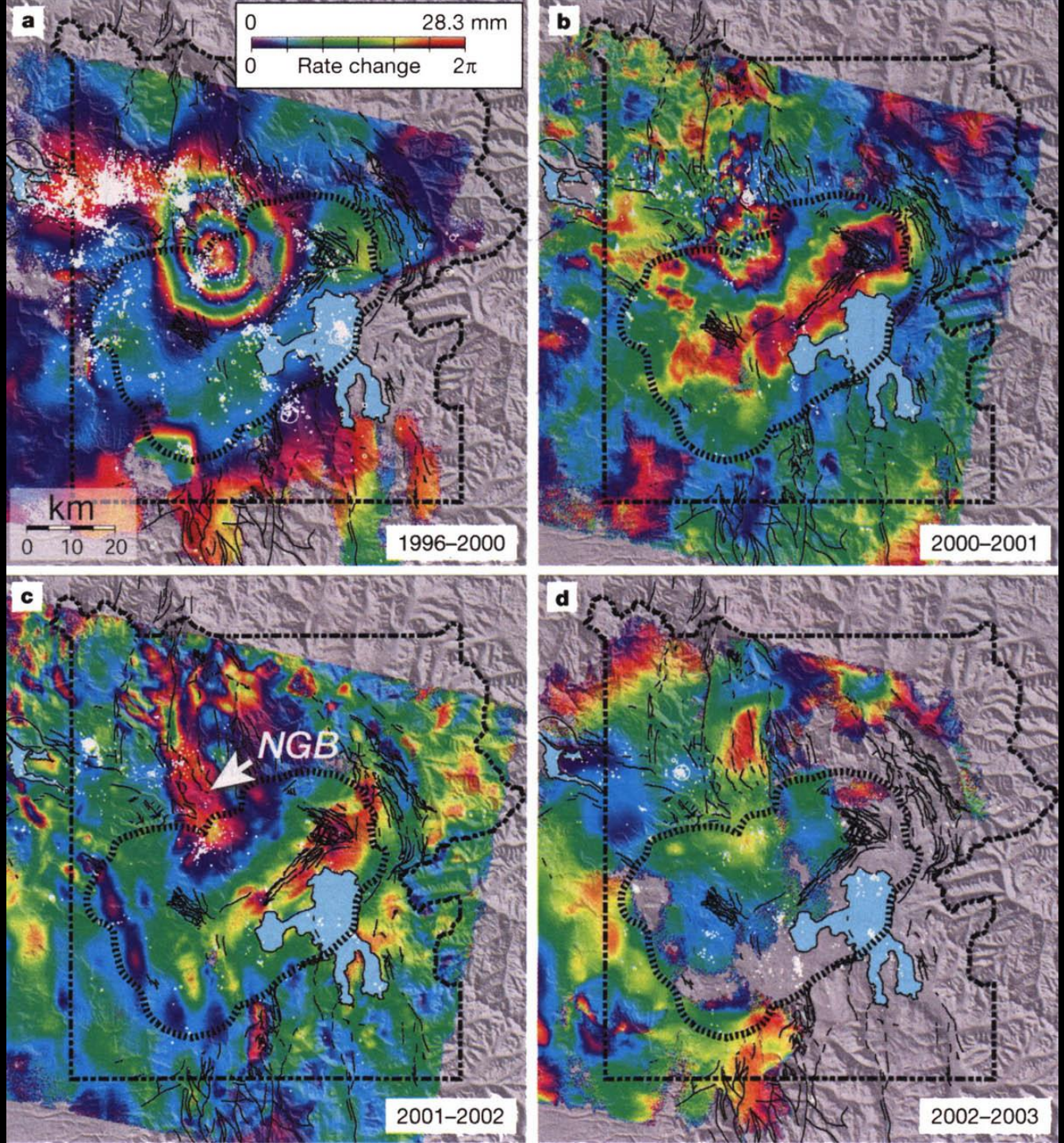
1996 – 2000

125 mm Uplift Centered at North Edge of Yellowstone Caldera

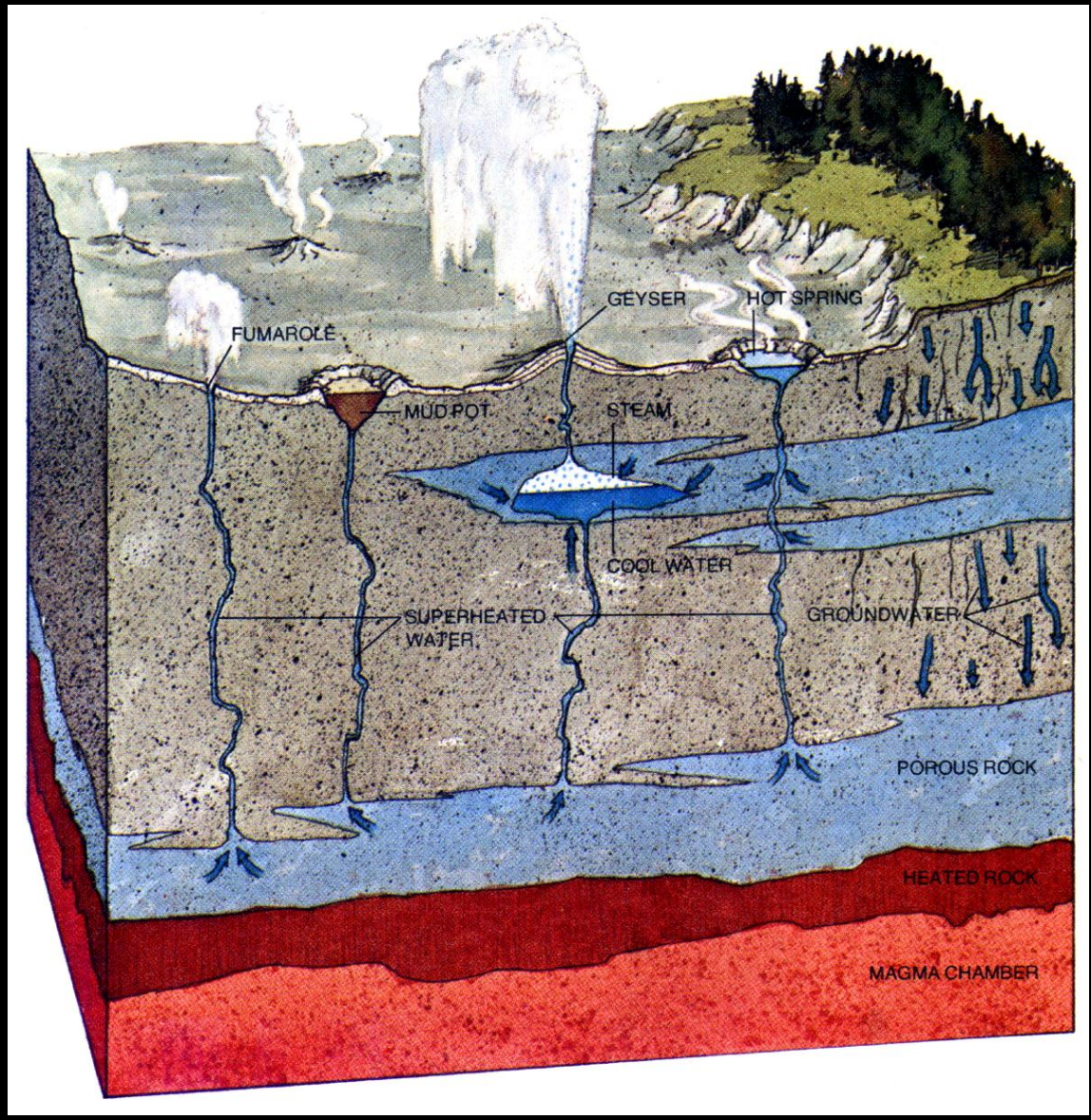
Each Spectra = 28 mm Uplift

Uplift Area = 35 x 40 km




a
0
28.3 mm
0
Rate change
2π
km
0 10 20
1996–2000
b
2000–2001
c
NGB
2001–2002
d
2002–2003


Remember, You're Nothing Without Me!
Finally, He's Going to Talk About Hot Springs



How Thermal Features Work





Chinese Spring

Mammoth Hot Springs

Churning Cauldron

Mammoth Hot Springs

Mammoth Hot Springs


Mammoth Hot Springs


Biscuit Basin

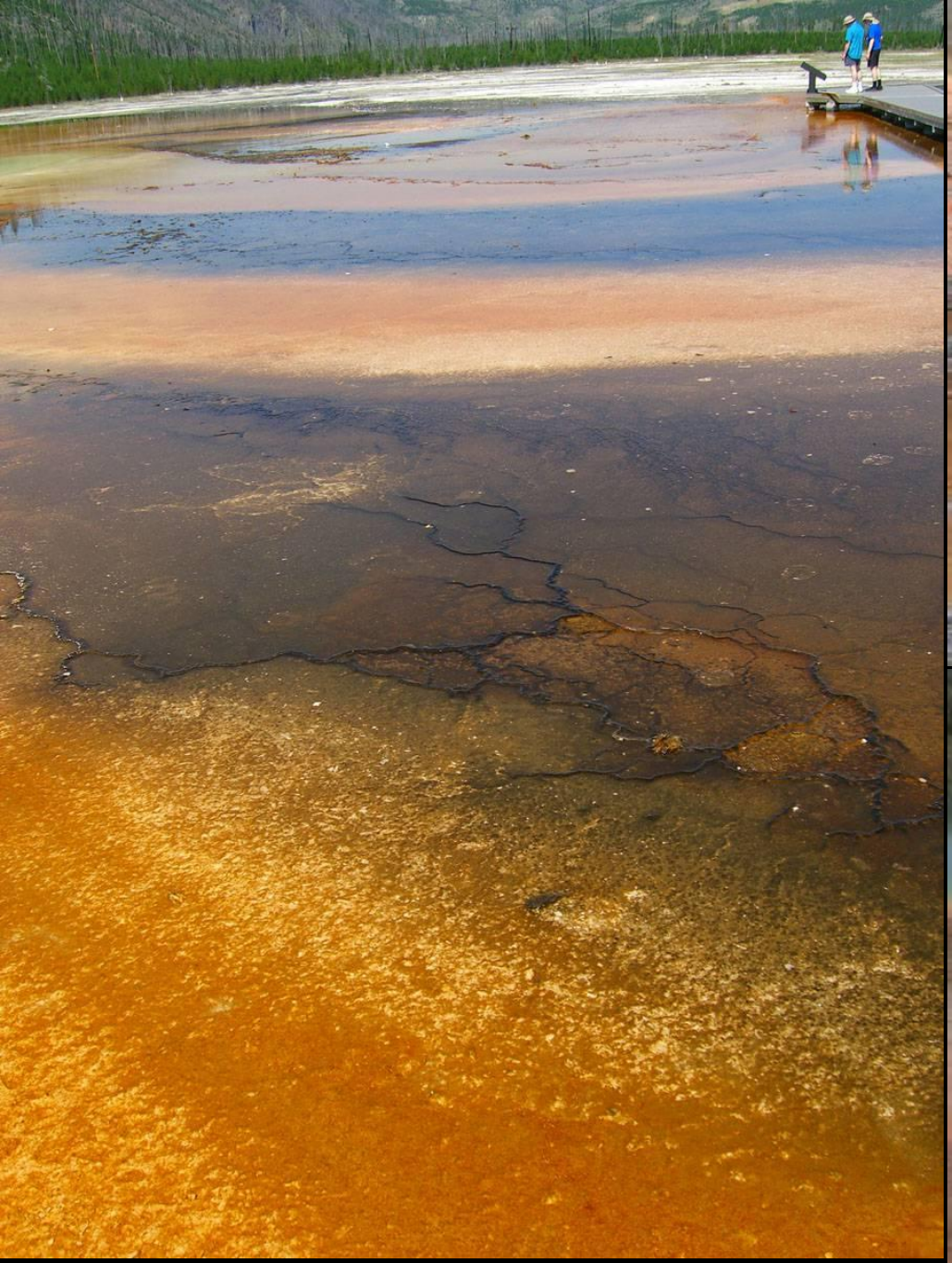
Biscuit Basin


Morning Glory Pool


Grand Prismatic Spring

Grand Prismatic Spring

Grand Prismatic Spring

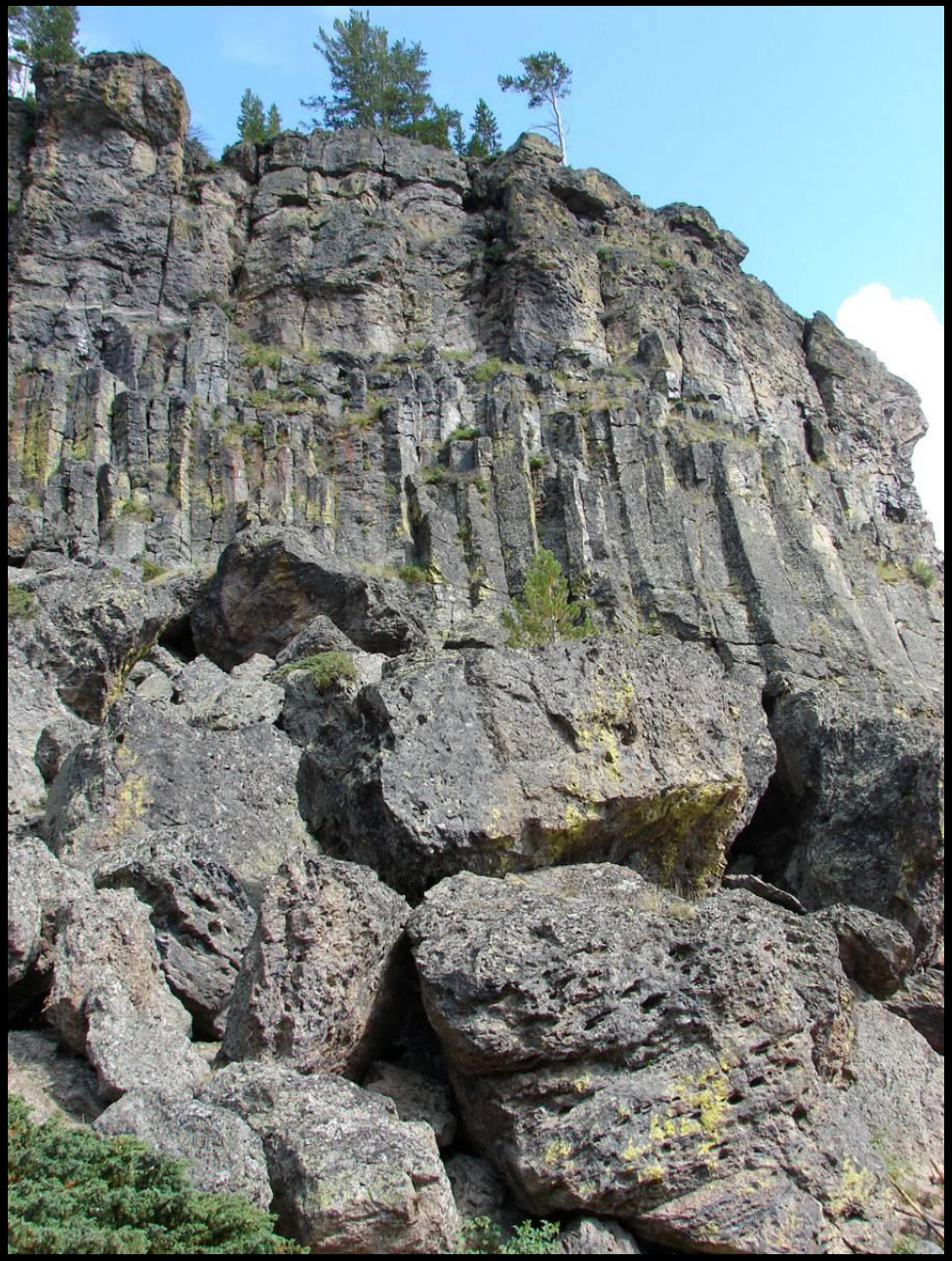


Grand Prismatic Spring


Grand Prismatic Spring

Yellowstone River Gorge


Obsidian Cliffs



Obsidian Cliffs


Obsidian Cliffs

Grand Canyon of the Yellowstone River

Hamfather IV

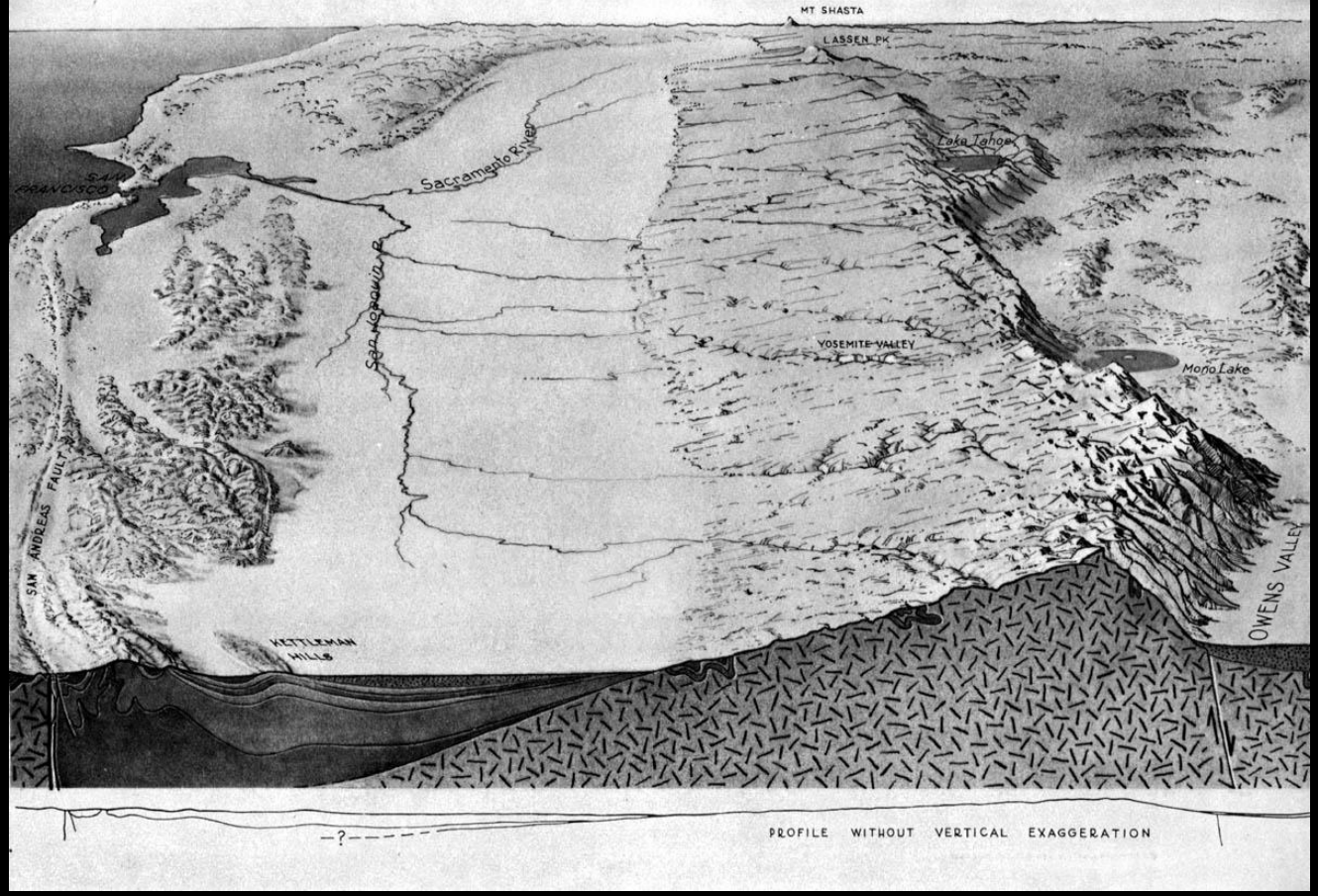
Now – You Are Eggsperts at Wyoming Geology

Geological Wonders of Yellowstone National Park, Wyoming

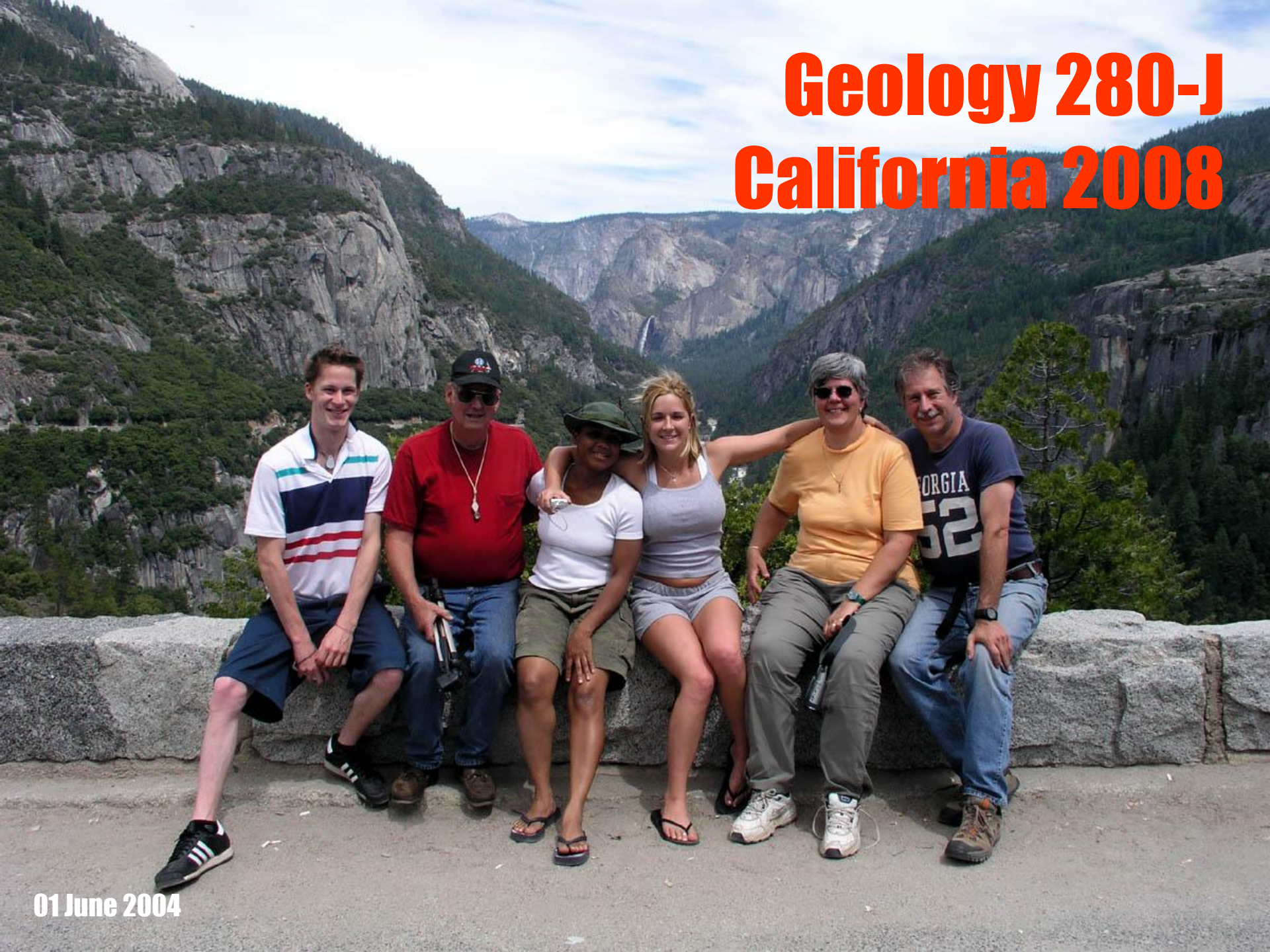
New York Mineral Club
10 October 2007

Charles Merguerian

Yellowstone IMAX



Well ... Are You Going to Tell Them About California?


Geology 280-J
California 2008
01 June 2004


Knockers


Serpentinite
24 May 2004

Royal Arches