Geological Wonders of Yellowstone National Park, Wyoming

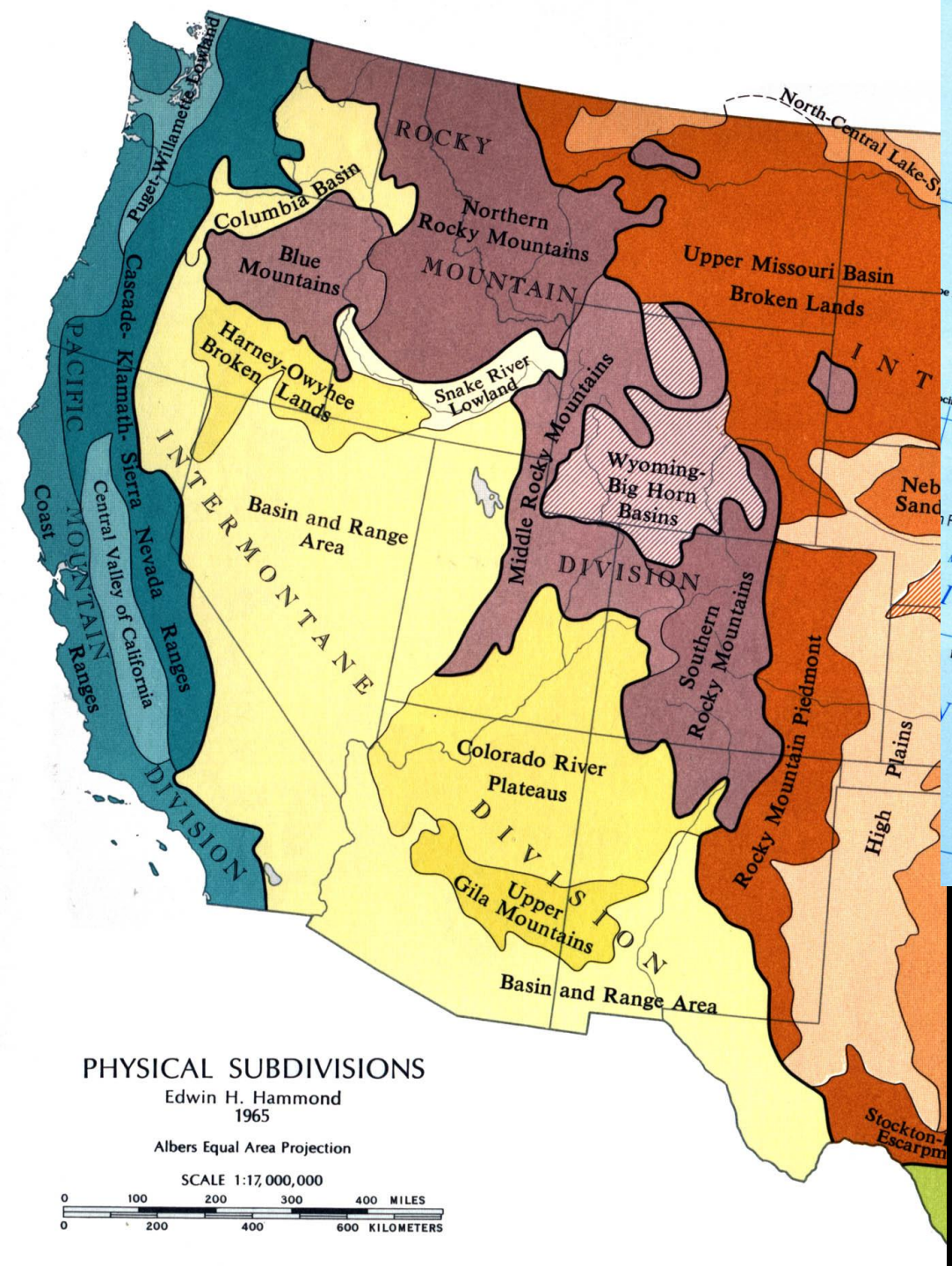
New York Mineral Show
03 March 2007

Charles Merguerian

Yellowstone IMAX

Hofstra University
Geology 280C
Geology For Teachers and Travelers

22-29 July 2006



PHYSICAL SUBDIVISIONS

Edwin H. Hammond
1965

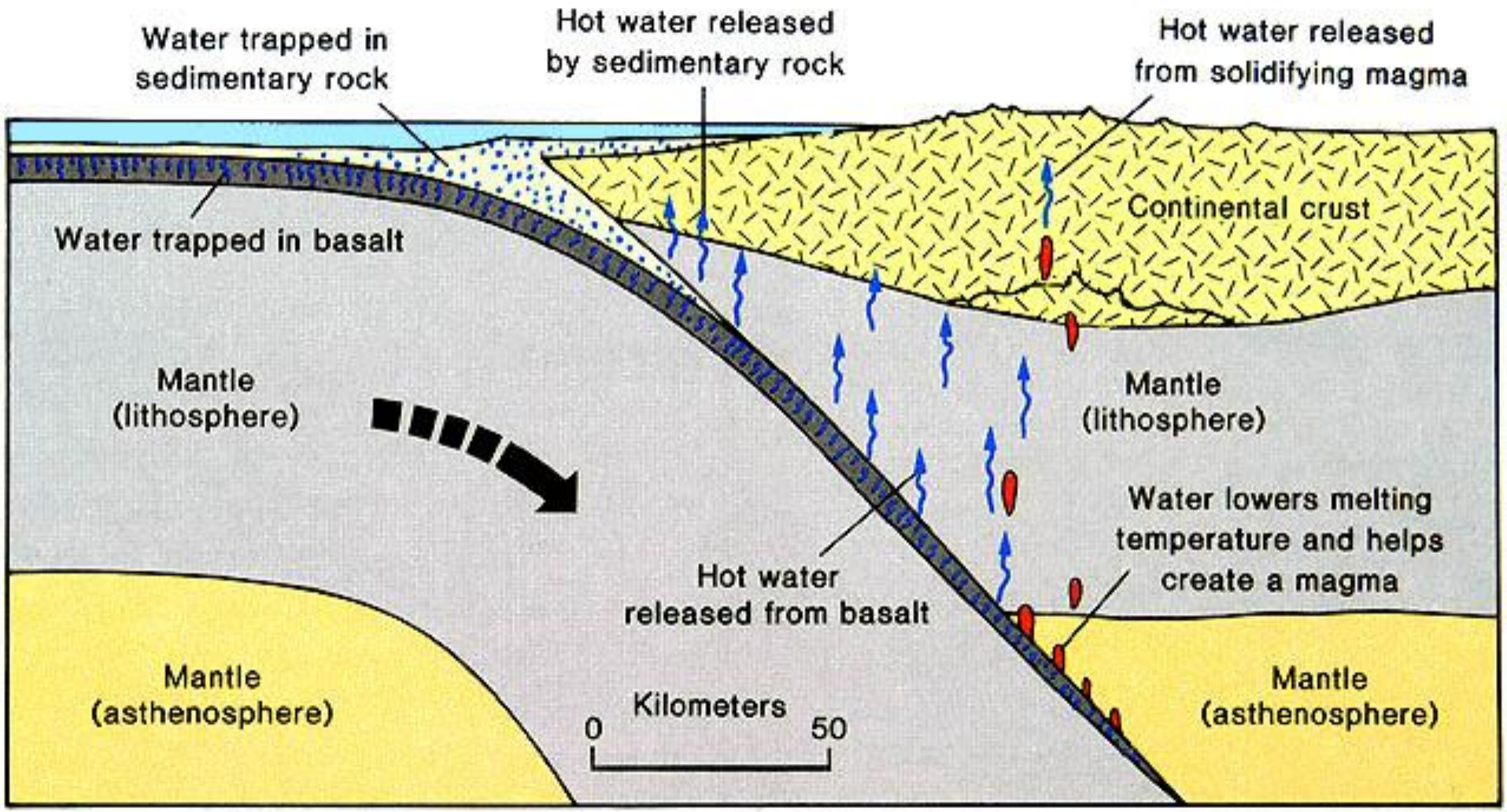
Albers Equal Area Projection

SCALE 1:17,000,000

0 100 200 300 400 MILES

0 200 400 600 KILOMETERS

Movement of water at convergent boundary




A319


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

Grand Tetons

9 Ma Tetons Fault Zone

Grand Tetons


Grand Teton

Grand Teton Range

Paleozoic Strata

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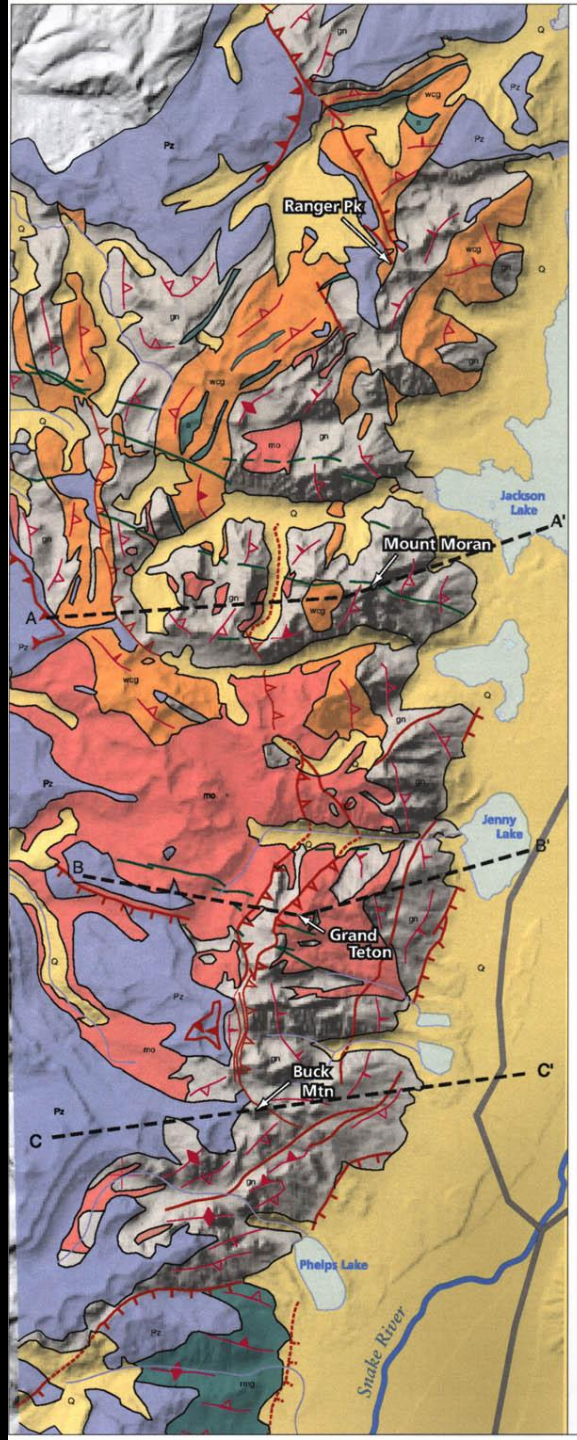
Proterozoic+

Granite Gneiss

Metagabbro



Quaternary deposits
(glacial, talus, and stream deposits; in cross sections shown only east of the range front)

Paleozoic rocks

Black Dikes

Mount Owen Granite

Rendezvous Metagabbro

Webb Canyon Gneiss

Metamorphic rocks
(gn, gneiss; a, amphibolite. Unit gn is chiefly layered gneiss, but includes rudely layered gneiss containing abundant large crystals of feldspar shown as Wag on the geologic map on Grand Teton Nation Park)

Fault, type uncertain
(dotted where concealed beneath younger deposits)

Normal fault
(teeth on downthrown block; dotted where concealed beneath younger deposits)

Reverse fault
(teeth on upthrown block; dotted where concealed beneath younger deposits)

Thrust fault
(teeth on upper plate)

Trend and inclination of foliation metamorphic rocks
(symbols show direction and amount of inclination)

0 – 30°

31 – 60°

61 – 80°

more than 80°

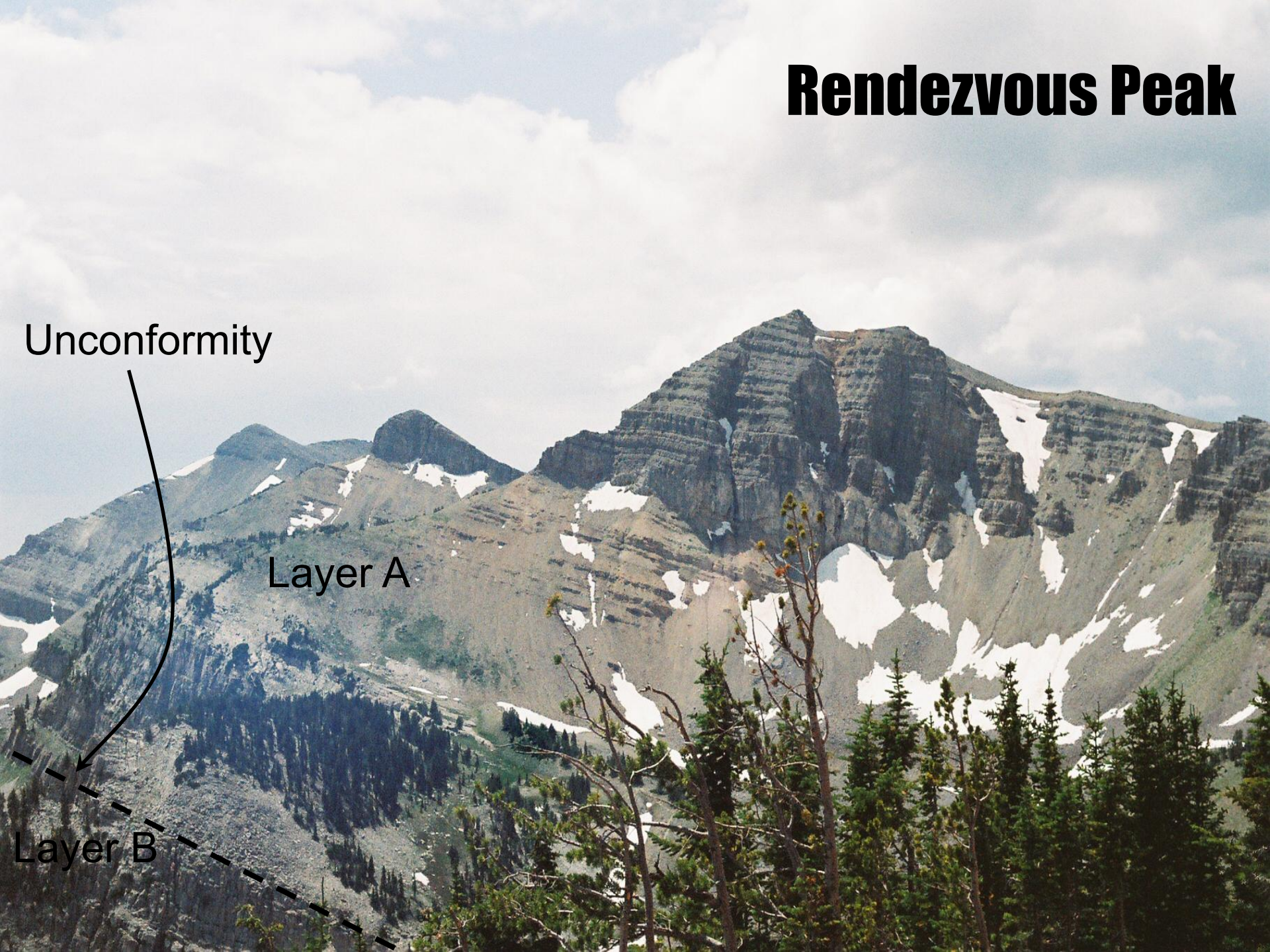
A — A'
Approximate line of section

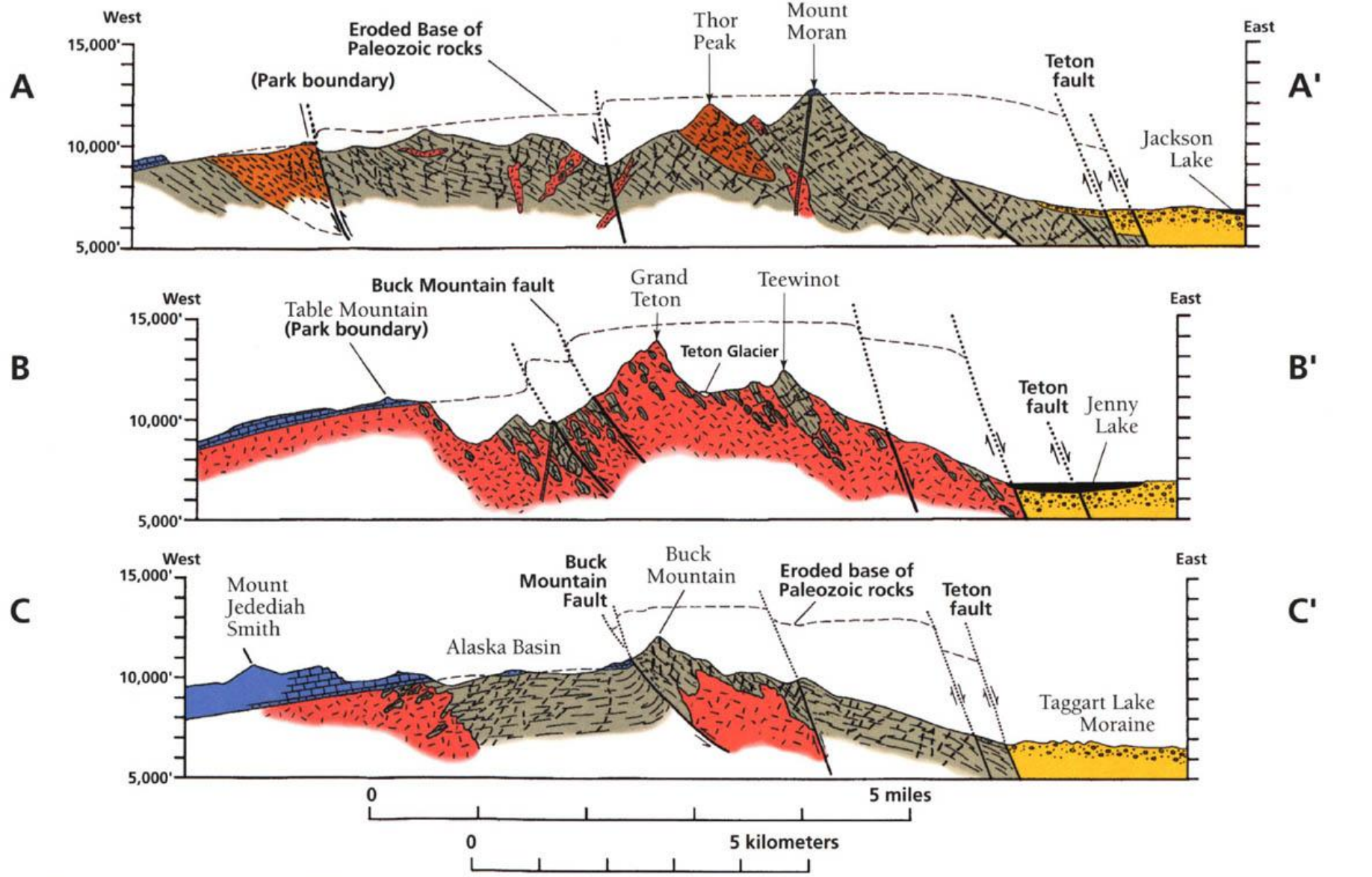
SCALE

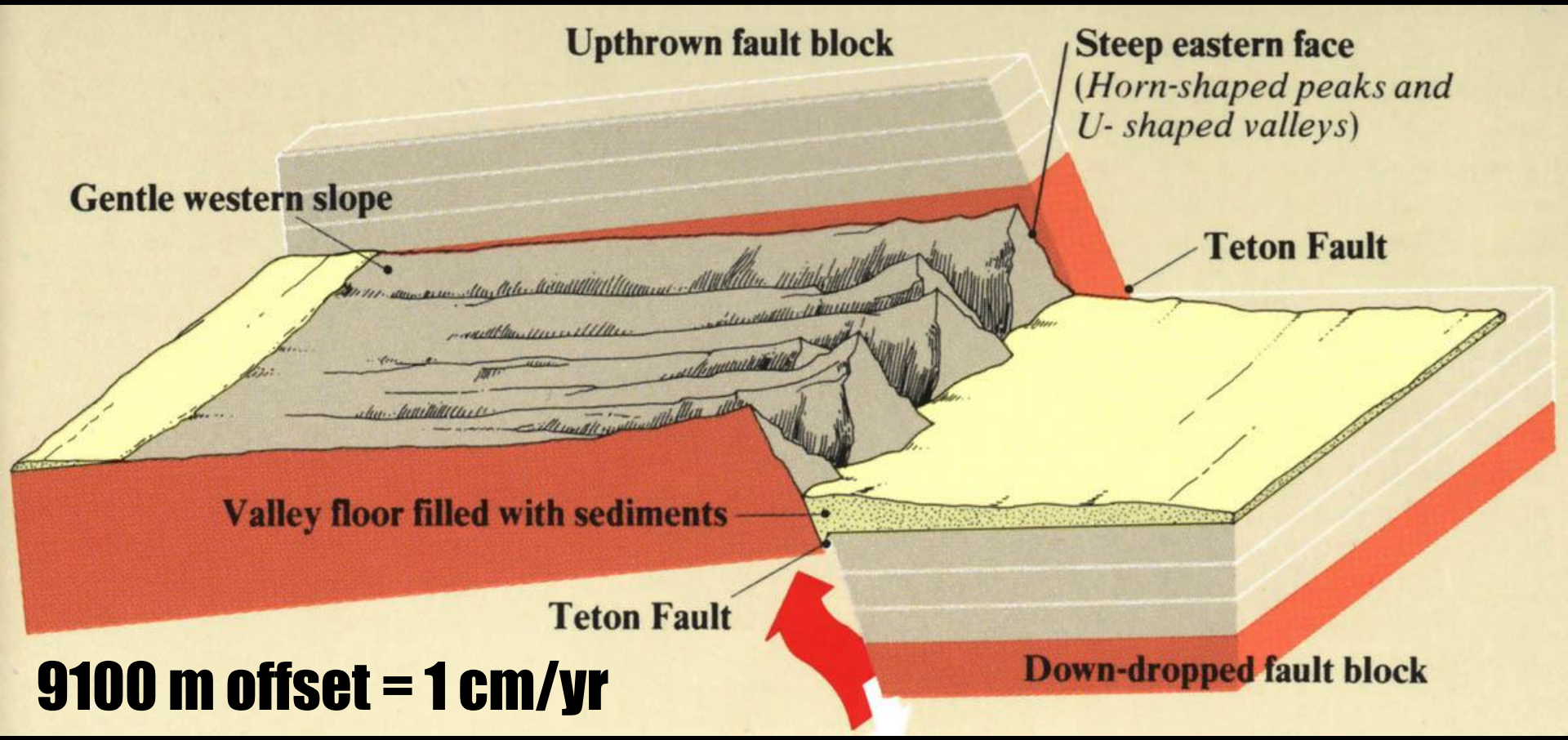
0 10 MILES

0 10 KM
~~~~~~~~~~~~~~

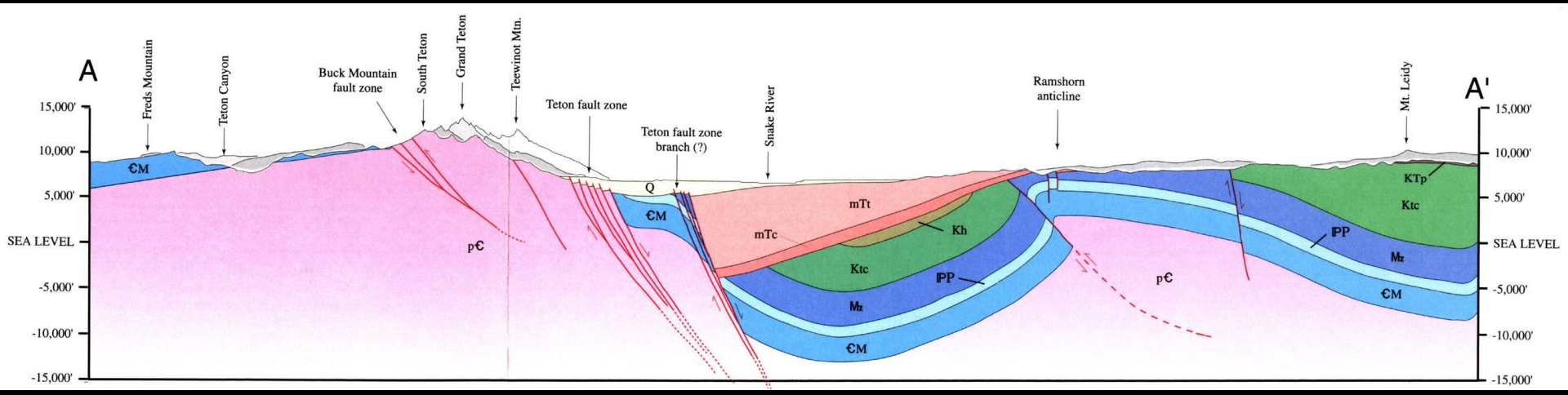
Rendezvous Peak



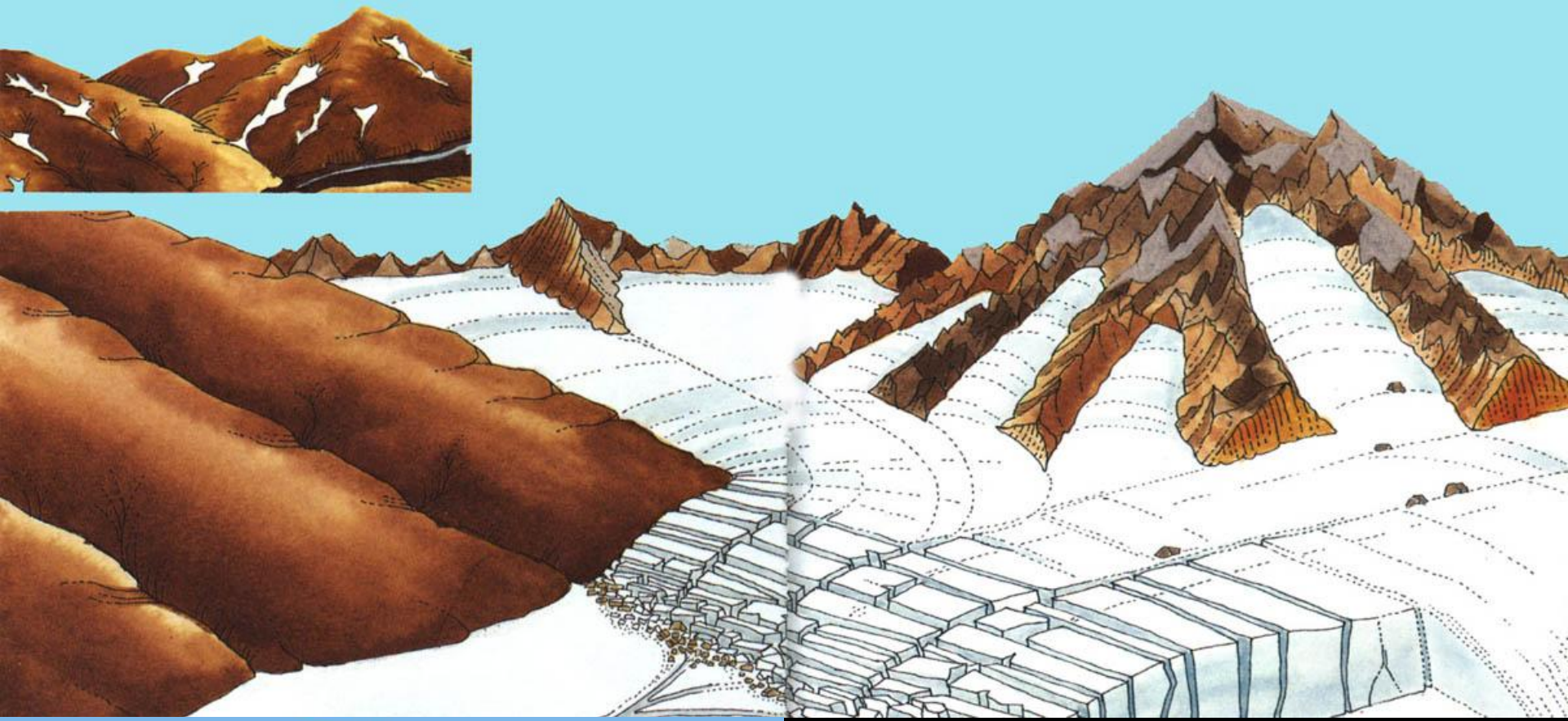

A
West
15,000'
10,000'
5,000'
Eroded Base of Paleozoic rocks
(Park boundary)
Thor Peak
Mount Moran
Teton fault
East
A'
Jackson Lake
B
West
15,000'
10,000'
5,000'
Buck Mountain fault
Table Mountain
(Park boundary)
Grand Teton
Teewinot
Teton Glacier
Teton fault
Jenny Lake
East
B'
C
West
15,000'
10,000'
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

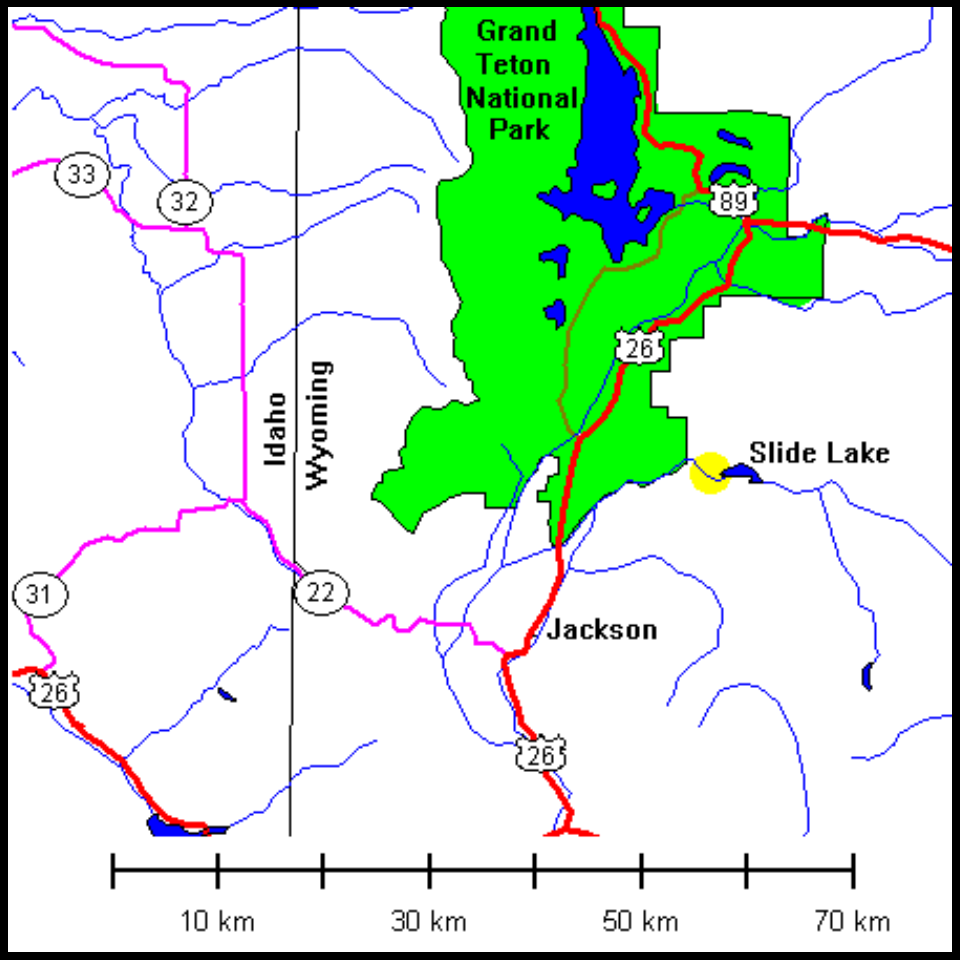


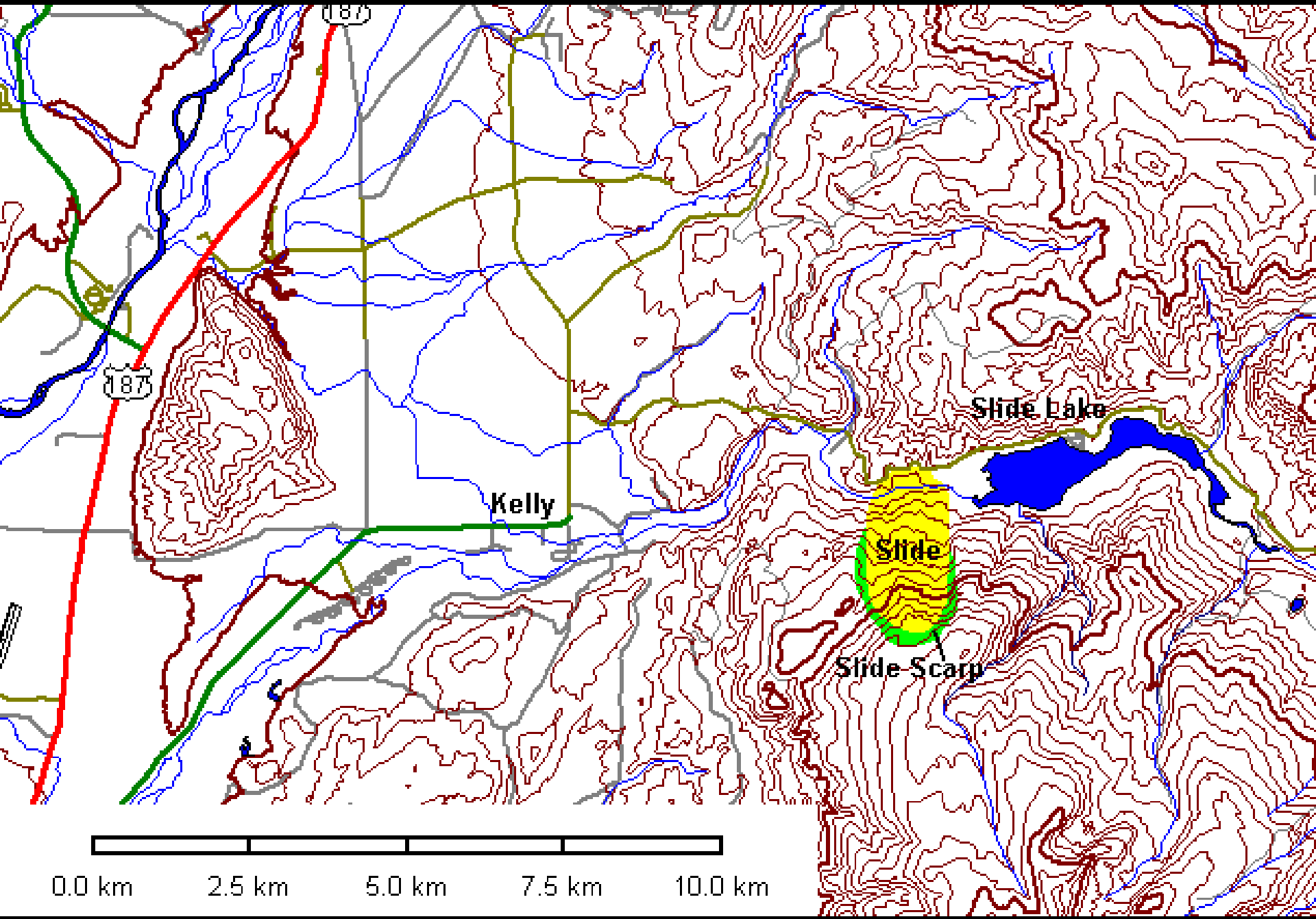

Mt. Moran



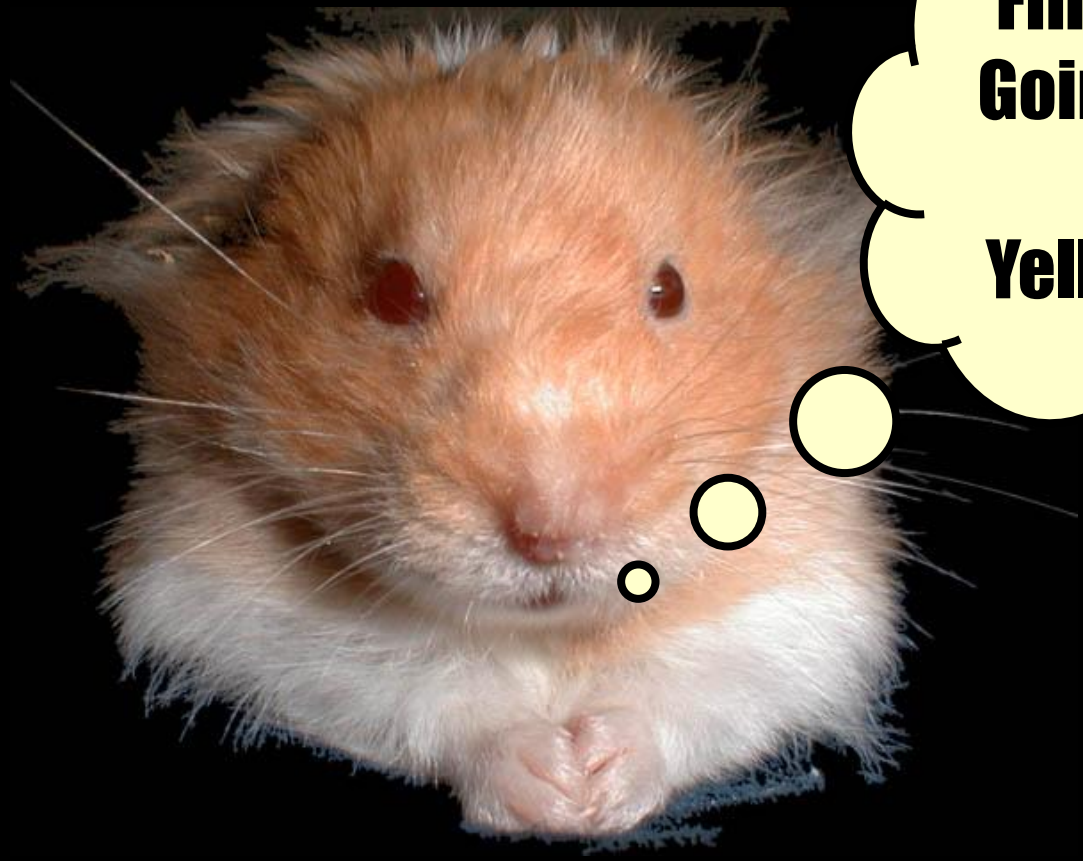
Gros Ventre Slide

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

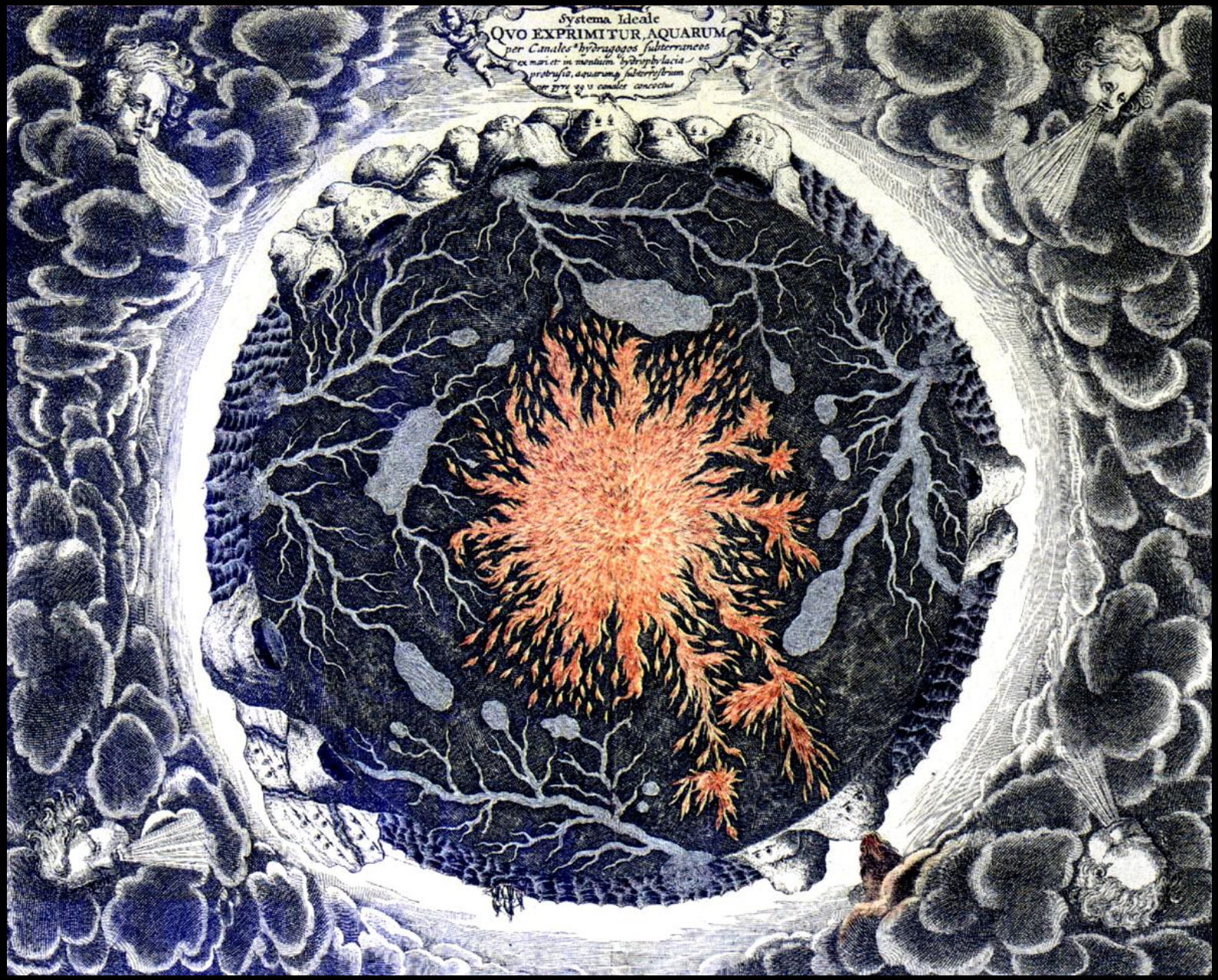



187
187
Kelly
Slide Lake
Slide
Slide Scarp
0.0 km
2.5 km
5.0 km
7.5 km
10.0 km

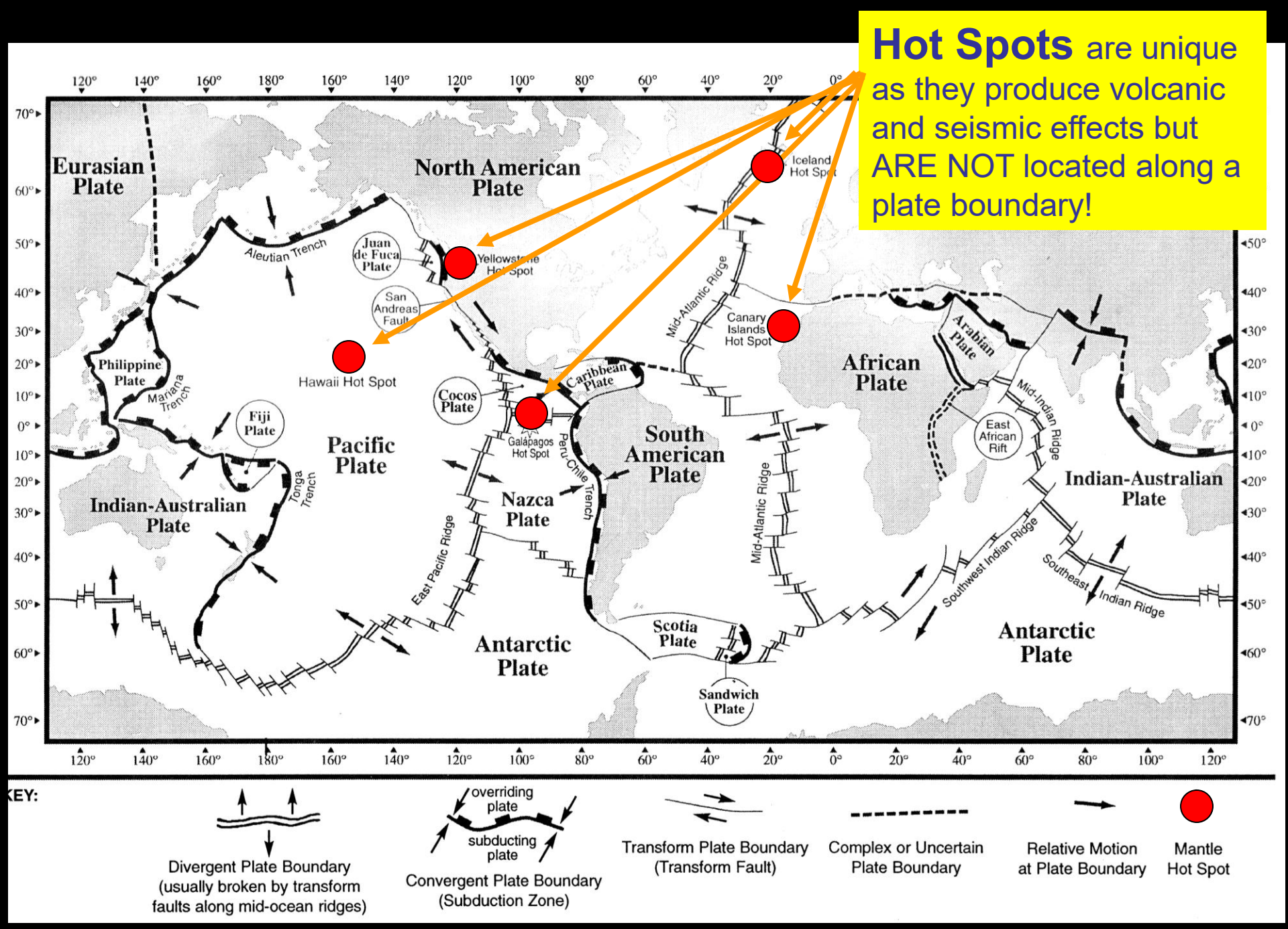

Lower Slide Lake

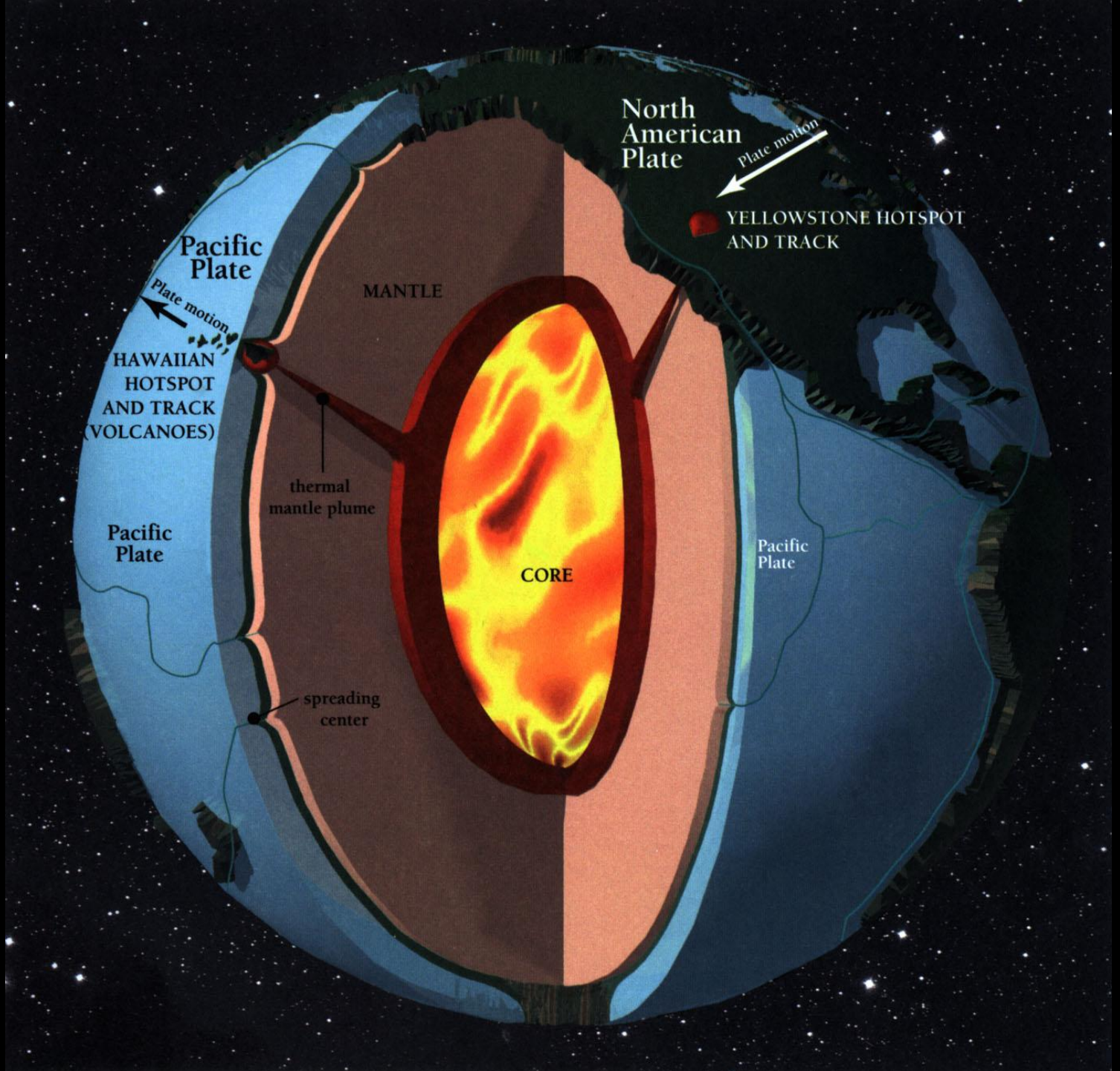

Finally, He's Going to Talk About Yellowstone

Hot Spot Field Trips

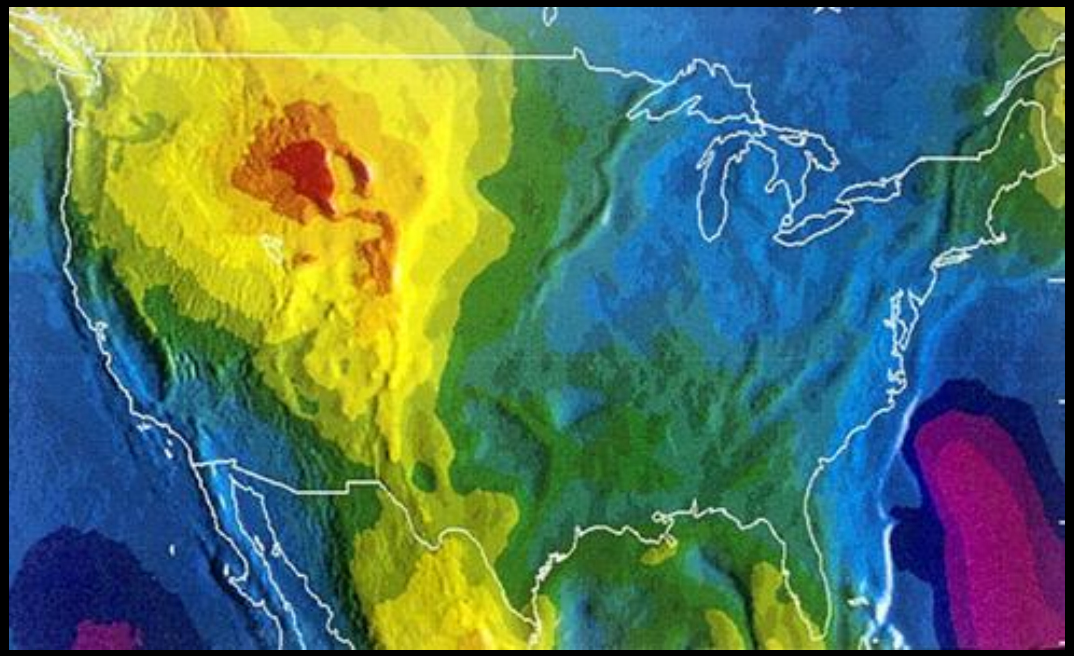


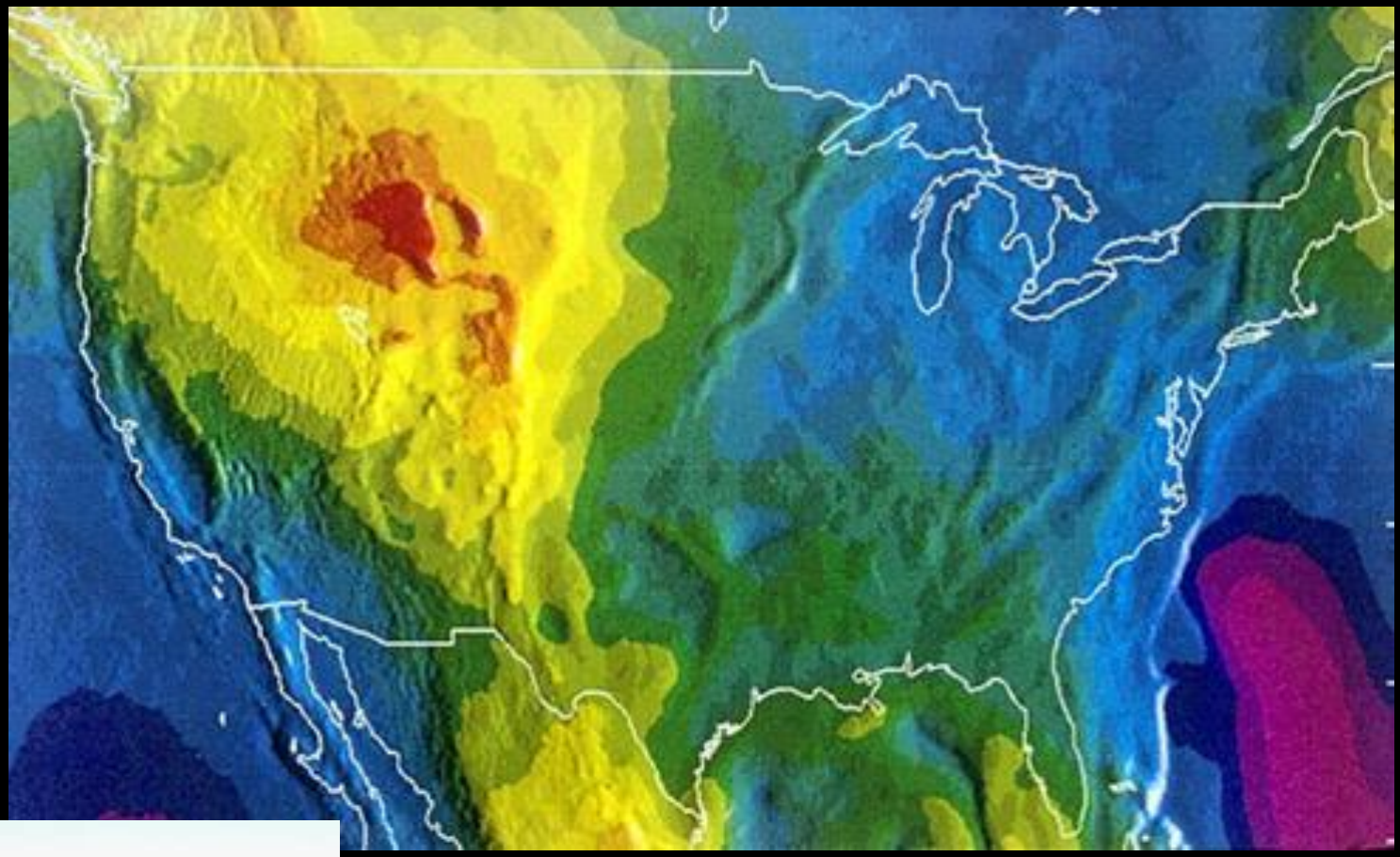
Kircher (1600s) – Mundus Subteraneos


Hot Spots are unique as they produce volcanic and seismic effects but ARE NOT located along a plate boundary!
Eurasian Plate
North American Plate
Iceland Hot Spot
Juan de Fuca Plate
Yellowstone Hot Spot
Aleutian Trench
San Andreas Fault
Mid-Atlantic Ridge
Canary Islands Hot Spot
Arabian Plate
African Plate
Philippine Plate
Mariana Trench
Hawaii Hot Spot
Cocos Plate
Caribbean Plate
Fiji Plate
Pacific Plate
Galápagos Hot Spot
Peru-Chile Trench
South American Plate
East African Rift
Mid-Indian Ridge
Indian-Australian Plate
Tonga Trench
Nazca Plate
East Pacific Ridge
Mid-Atlantic Ridge
Southwest Indian Ridge
Southeast Indian Ridge
Antarctic Plate
Scotia Plate
Sandwich Plate
KEY:
Divergent Plate Boundary (usually broken by transform faults along mid-ocean ridges)
overriding plate
subducting plate
Convergent Plate Boundary (Subduction Zone)
Transform Plate Boundary (Transform Fault)
Complex or Uncertain Plate Boundary
Relative Motion at Plate Boundary
Mantle Hot Spot

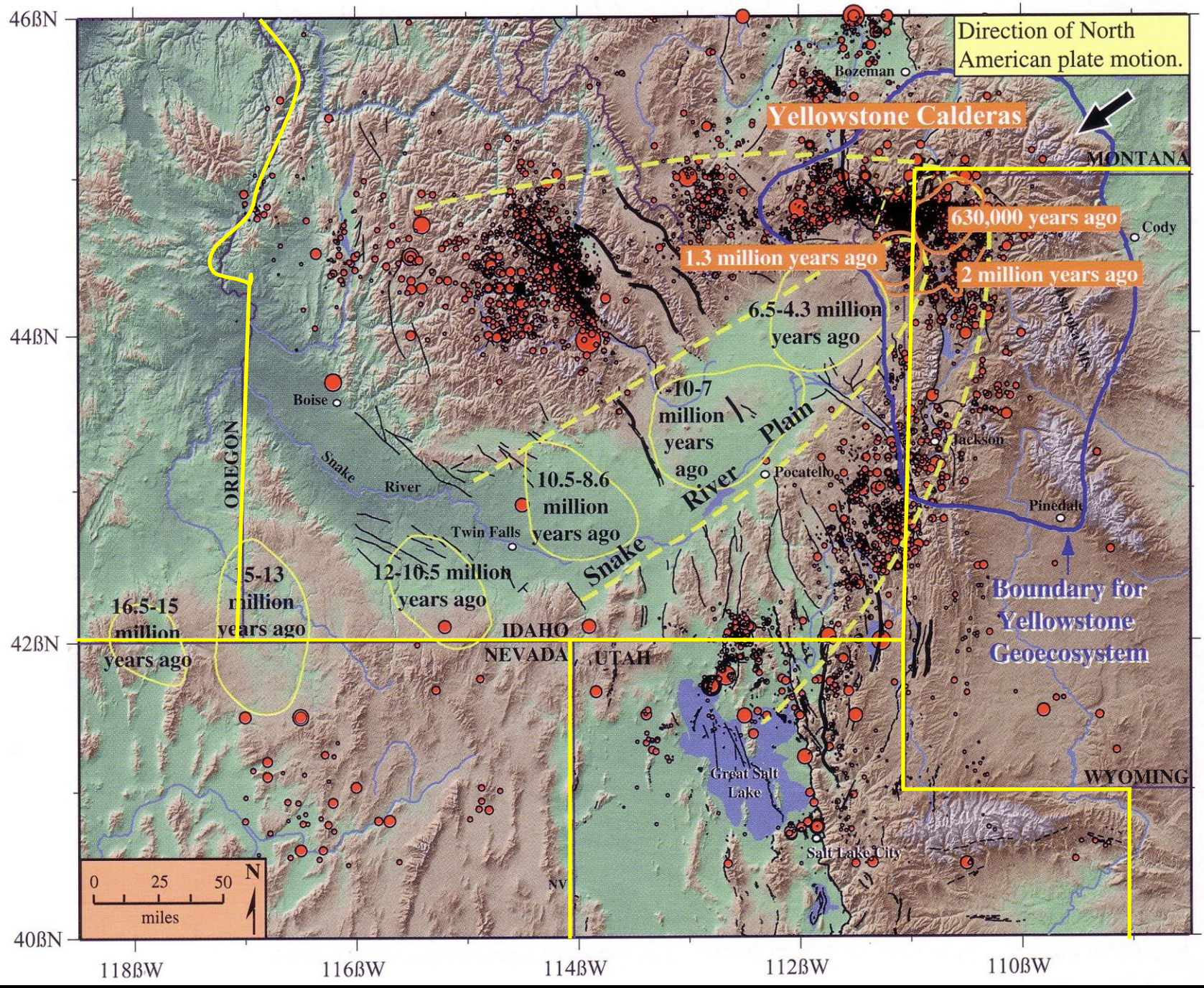

North American Plate
Plate motion
YELLOWSTONE HOTSPOT AND TRACK
Pacific Plate
Plate motion
HAWAIIAN HOTSPOT AND TRACK (VOLCANOES)
MANTLE
thermal mantle plume
CORE
Pacific Plate
Pacific Plate
spreading center

- 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 breathing

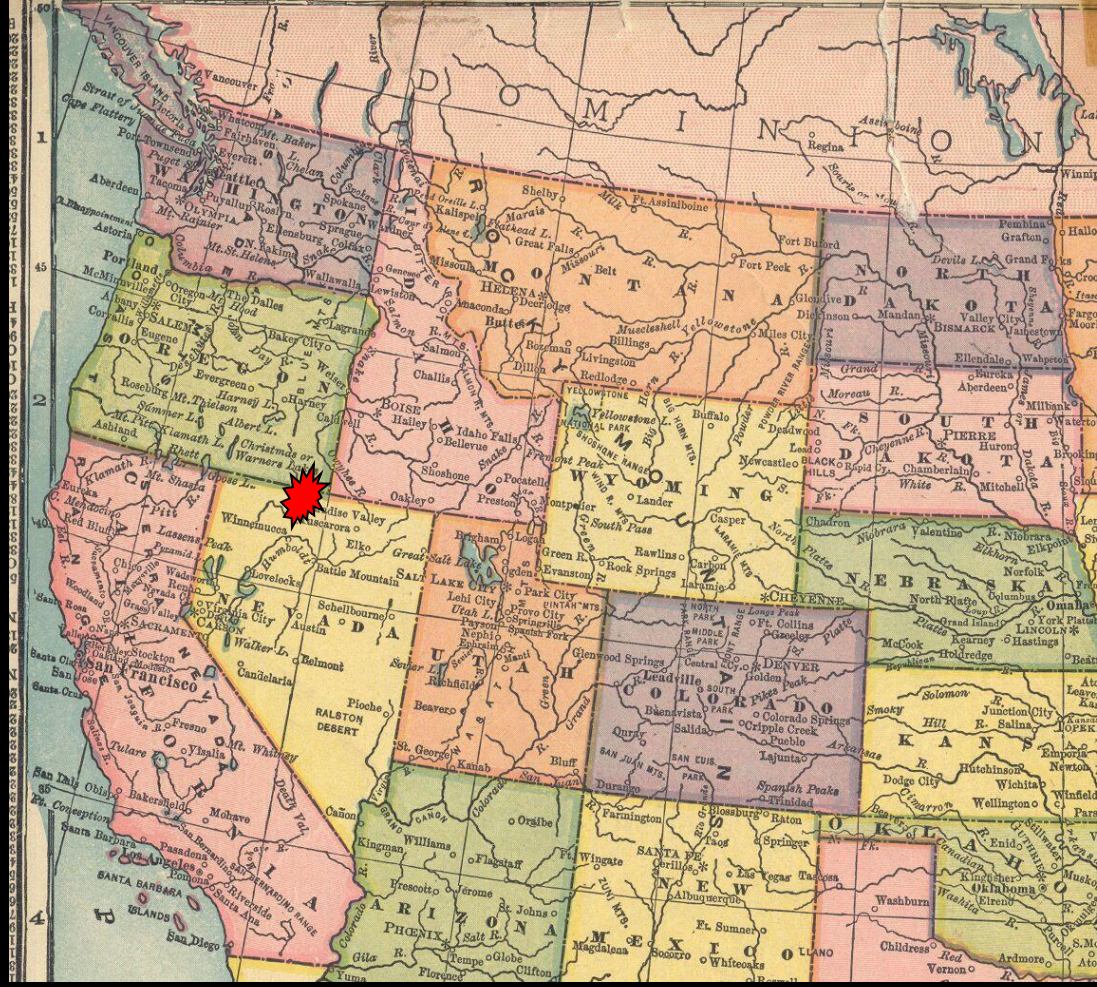




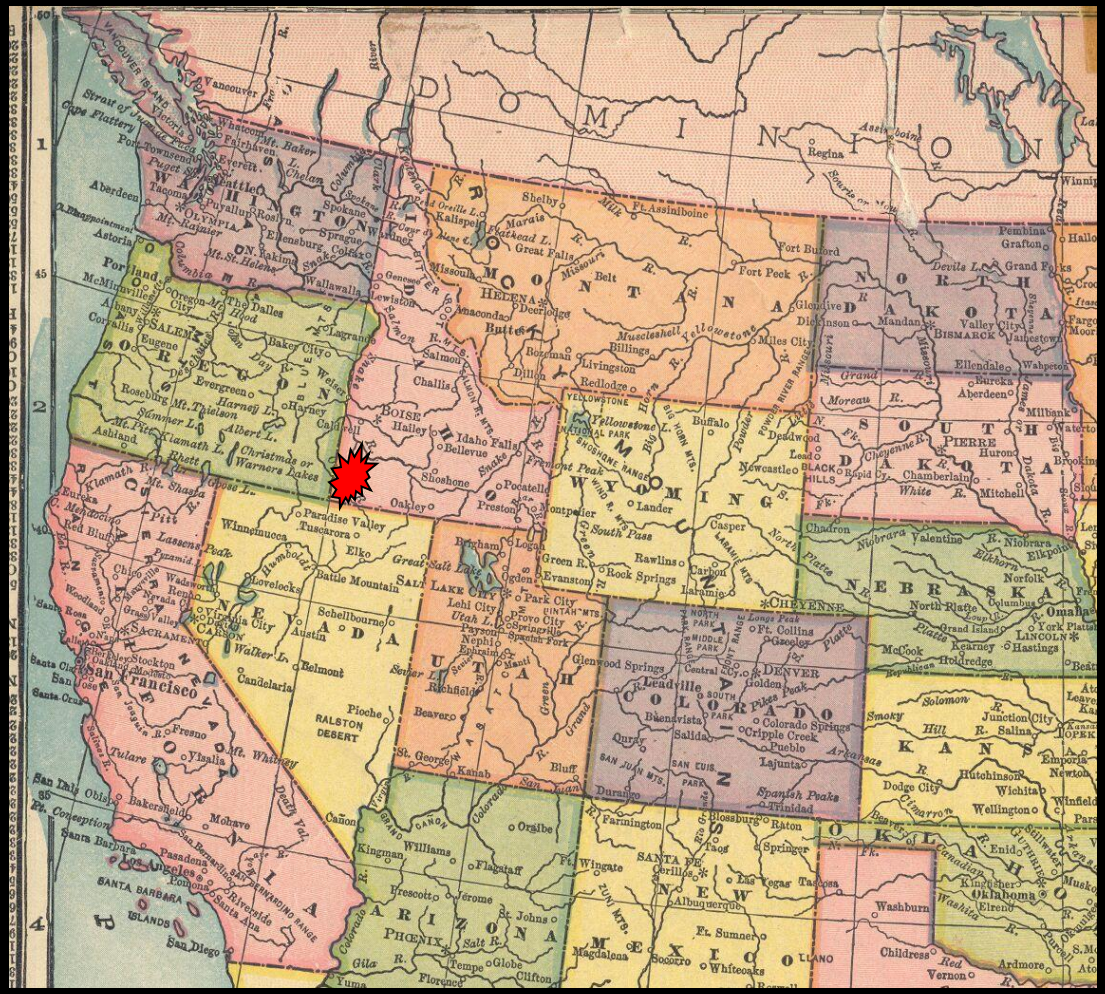
Yellowstone Hot Spot Track


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
0 25 50
miles
N
46ßN
44ßN
42ßN
40ßN
118ßW
116ßW
114ßW
112ßW
110ßW

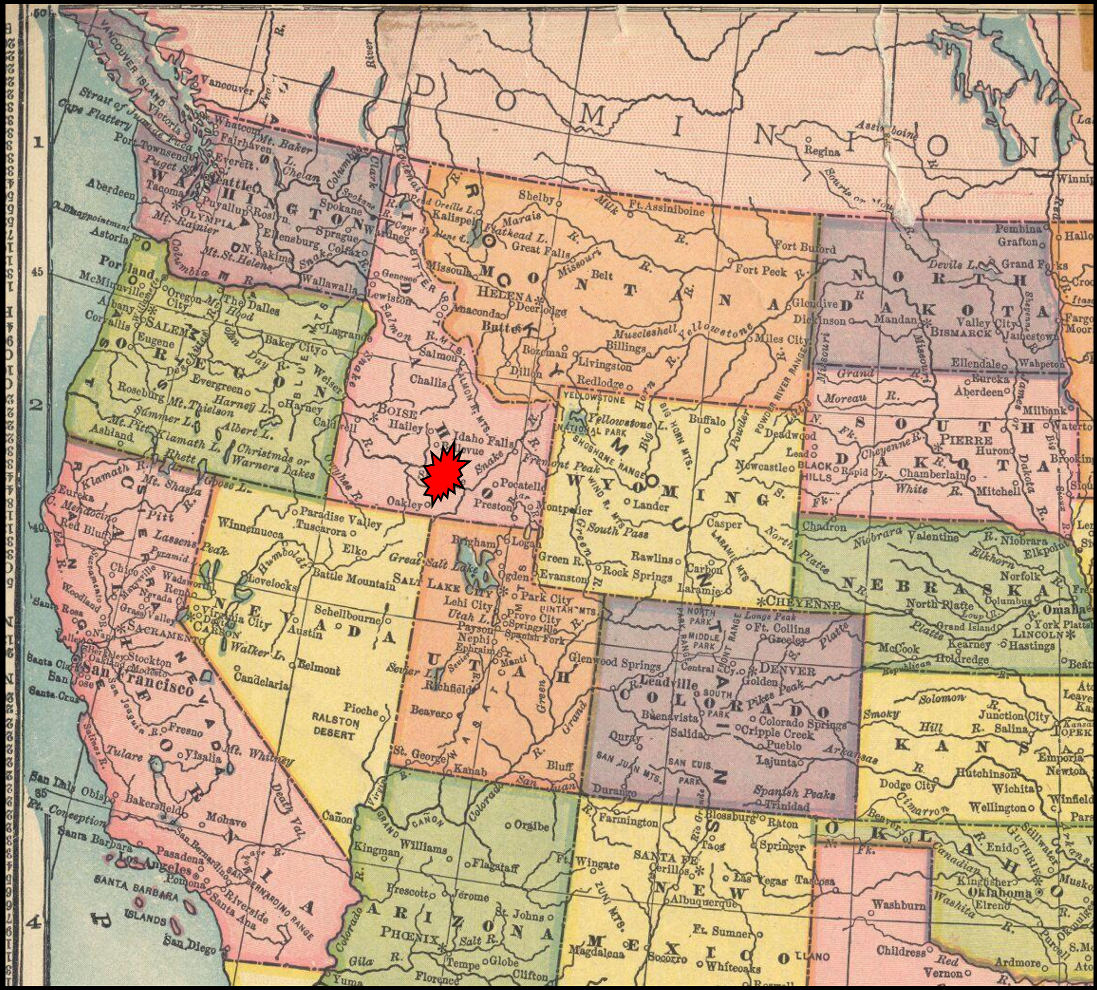
Hot Spot Tracks Movement of the North American Plate Over the Yellowstone Hot Spot



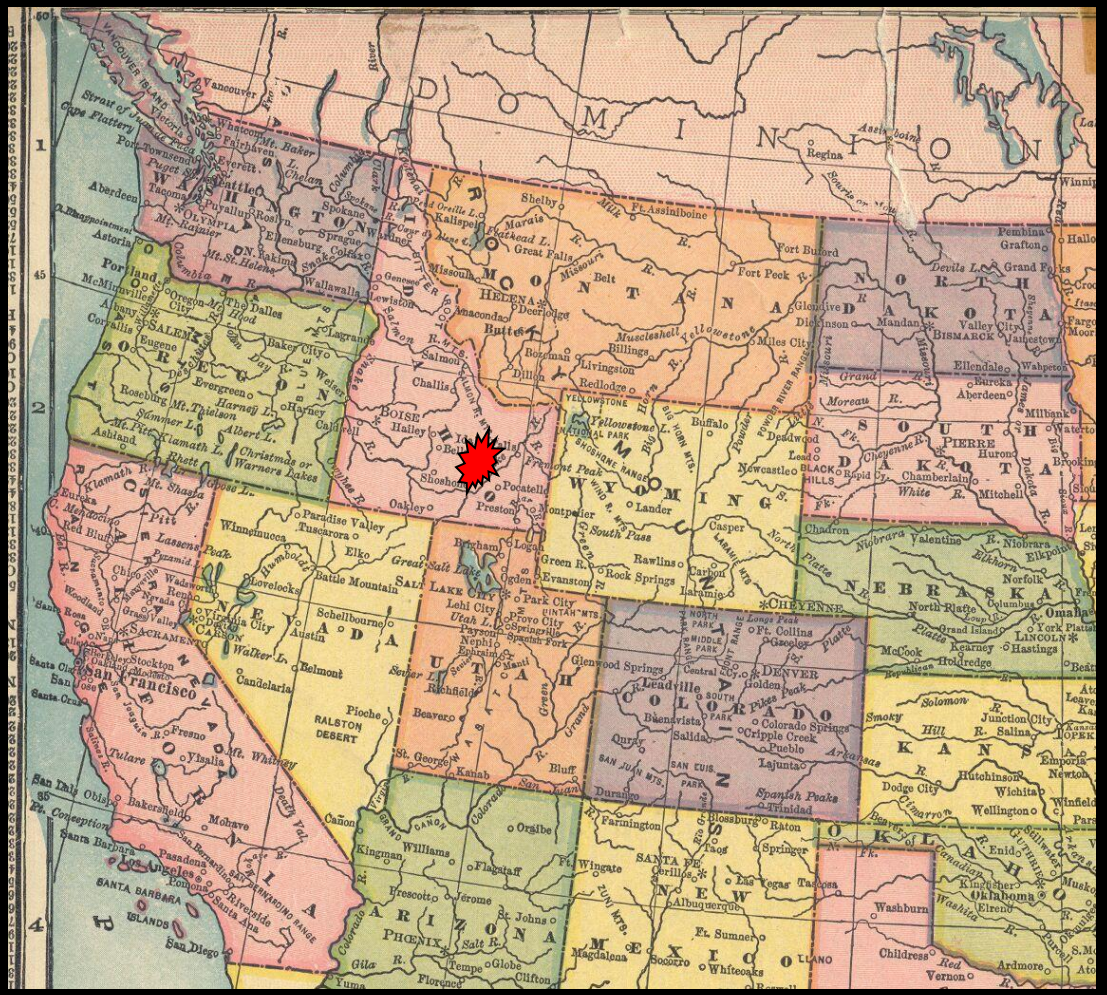
16.5 - 15 Ma - Miocene



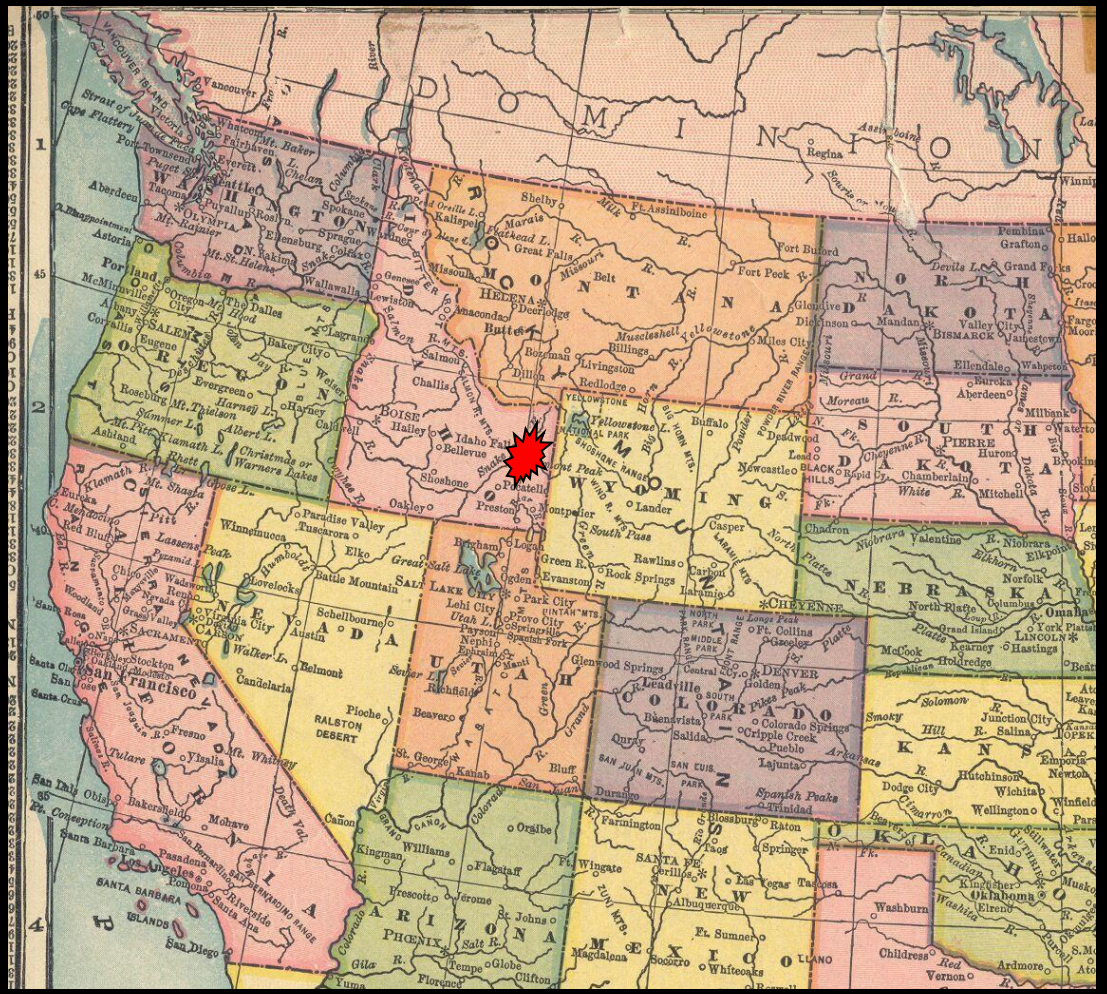
15 – 13 Ma - Miocene



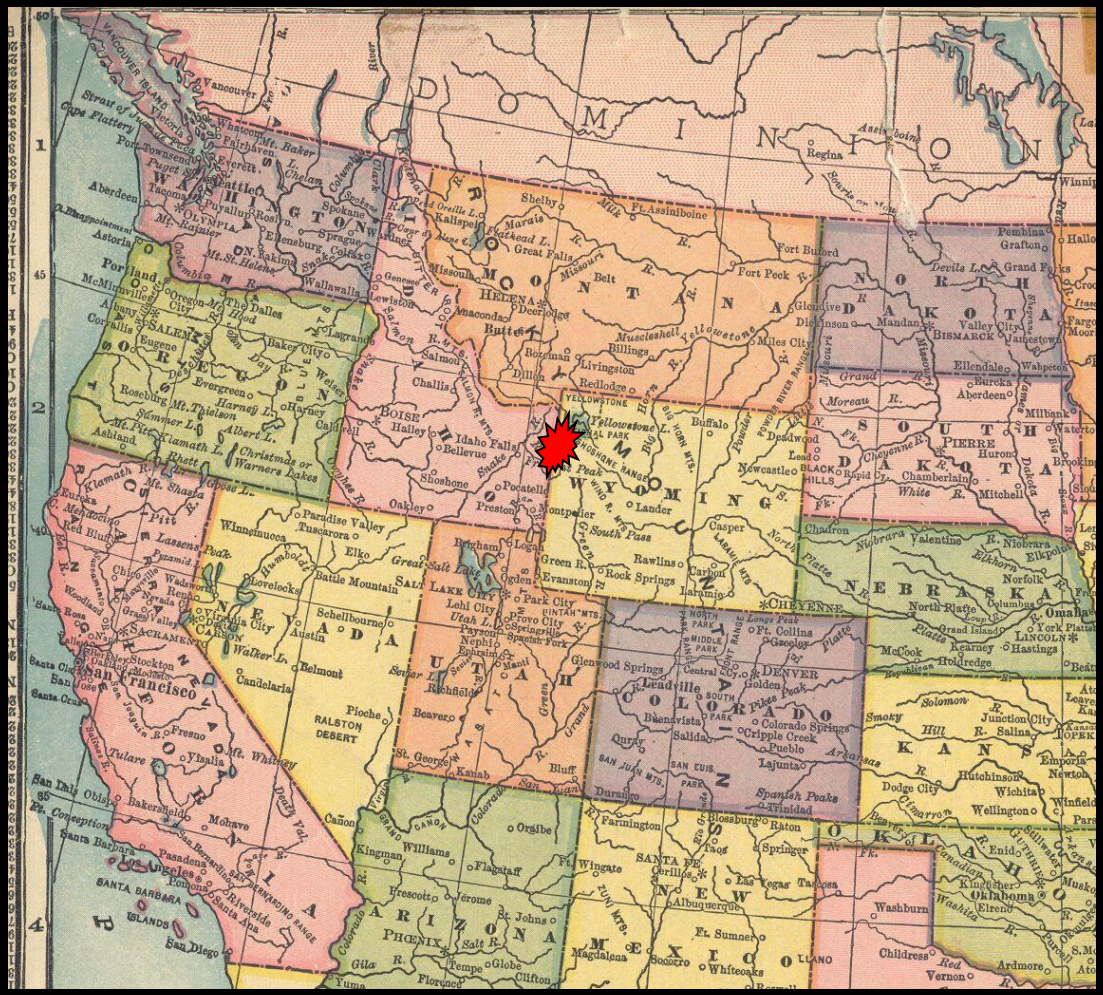
10.5 – 8.6 Ma - Miocene



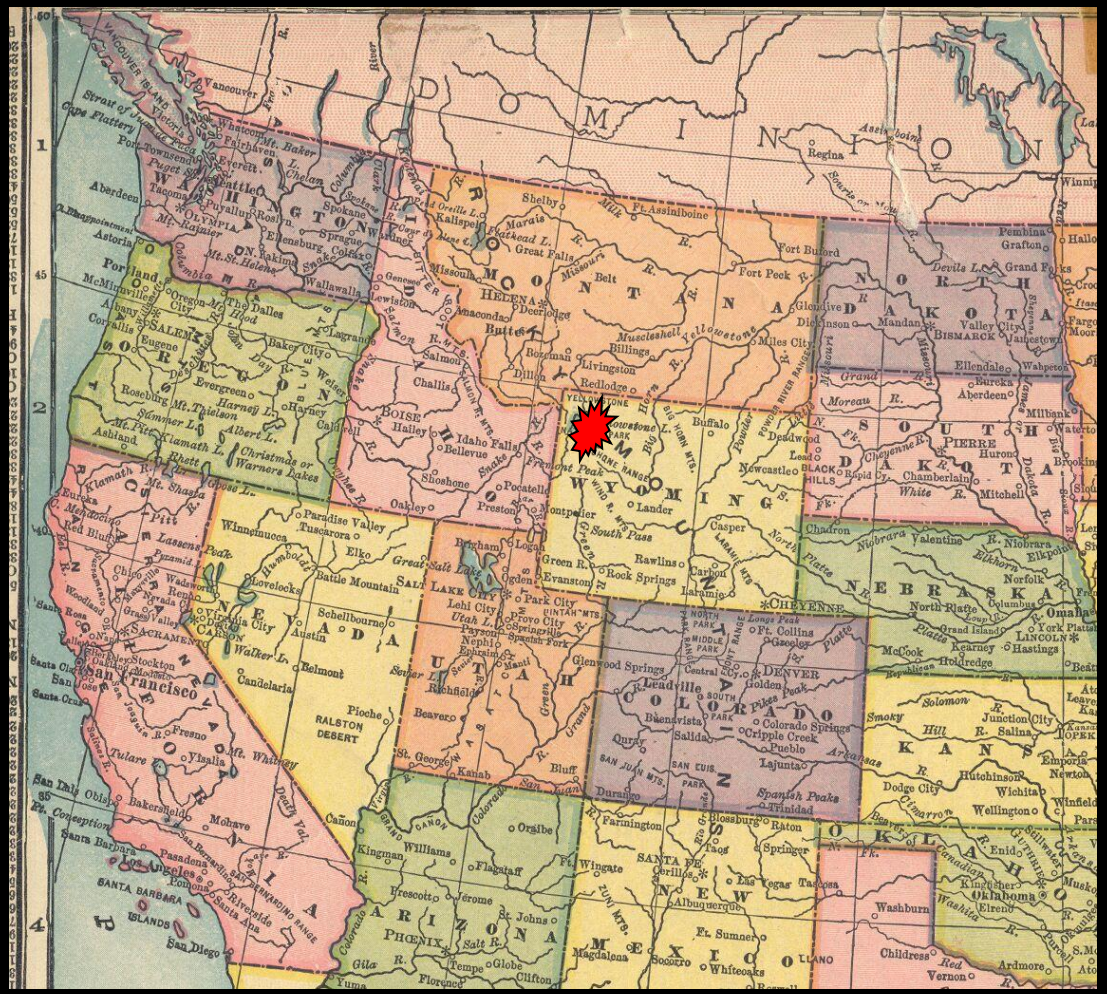
10 – 7 Ma - Miocene



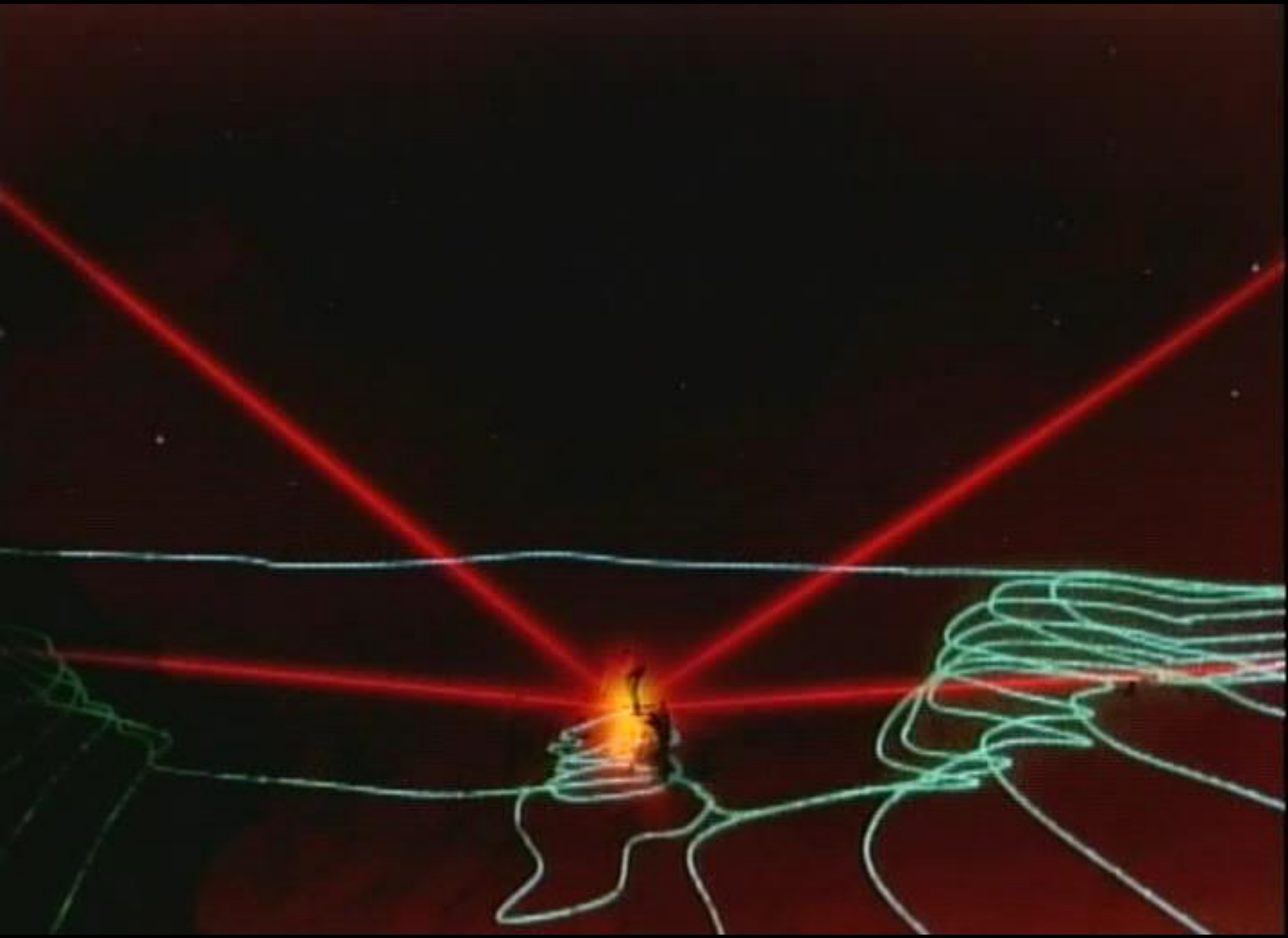
6.5 – 4.3 Ma – Miocene/Pliocene

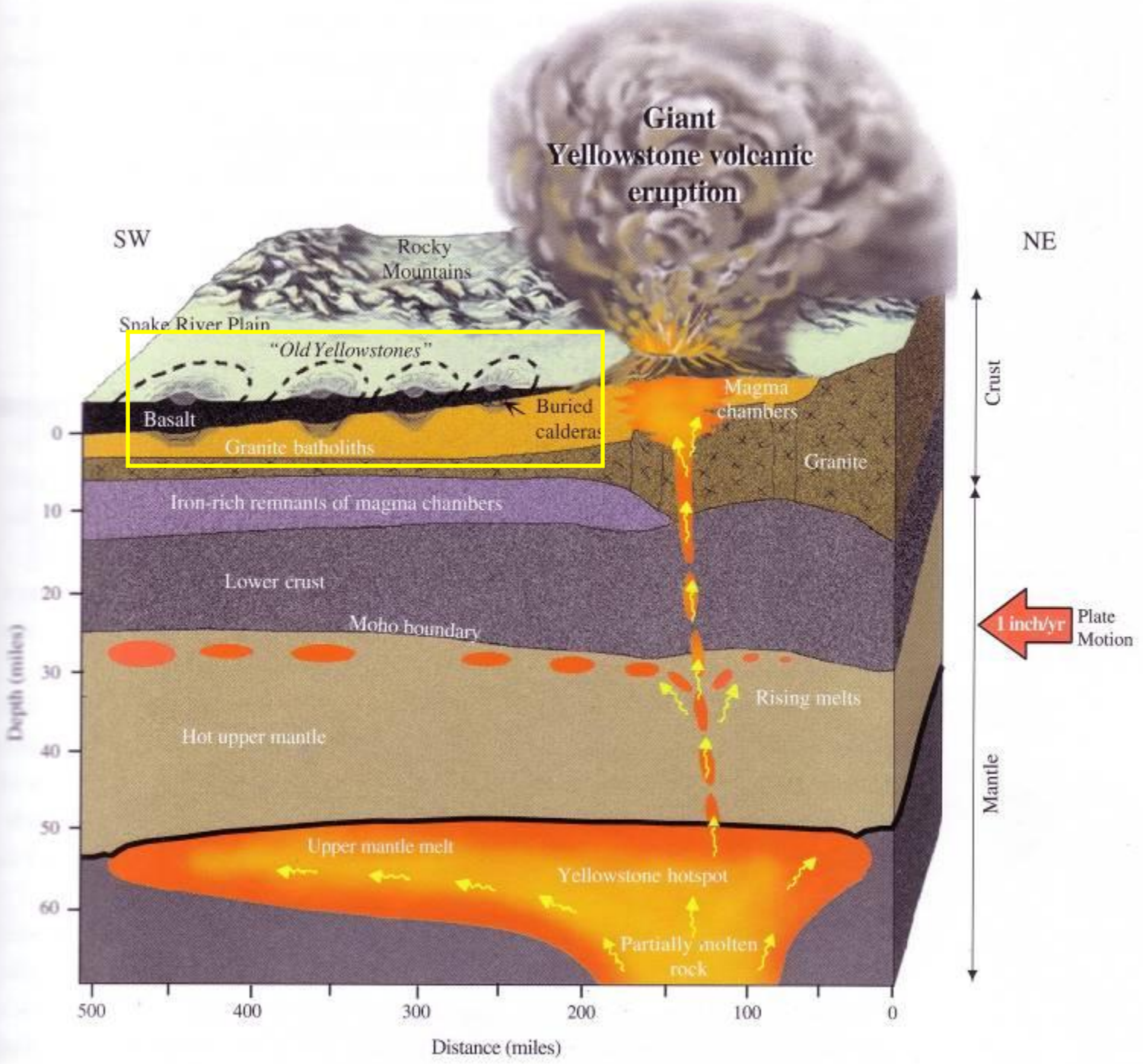


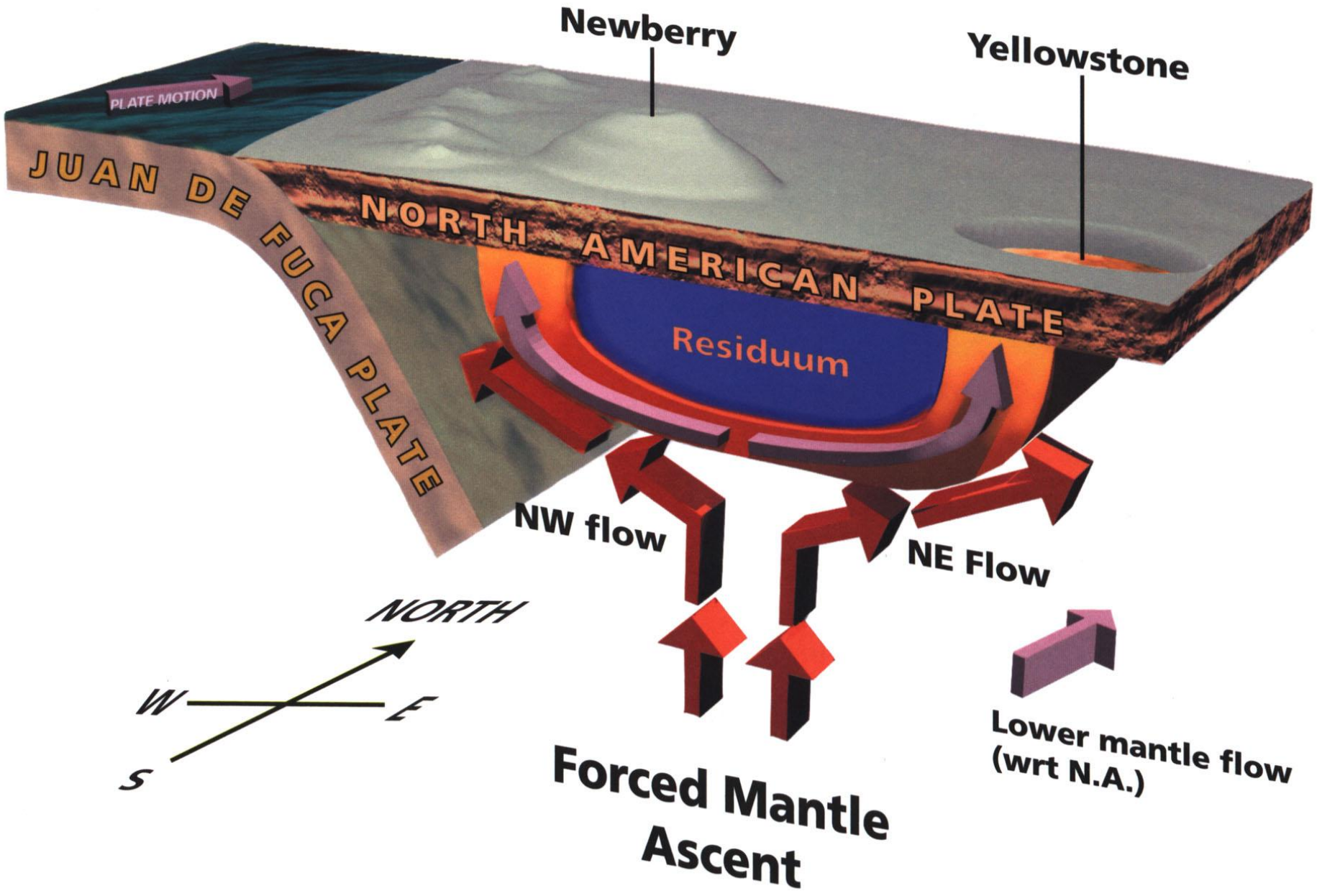
2 – 1.3 Ma – Pliocene/Pleistocene

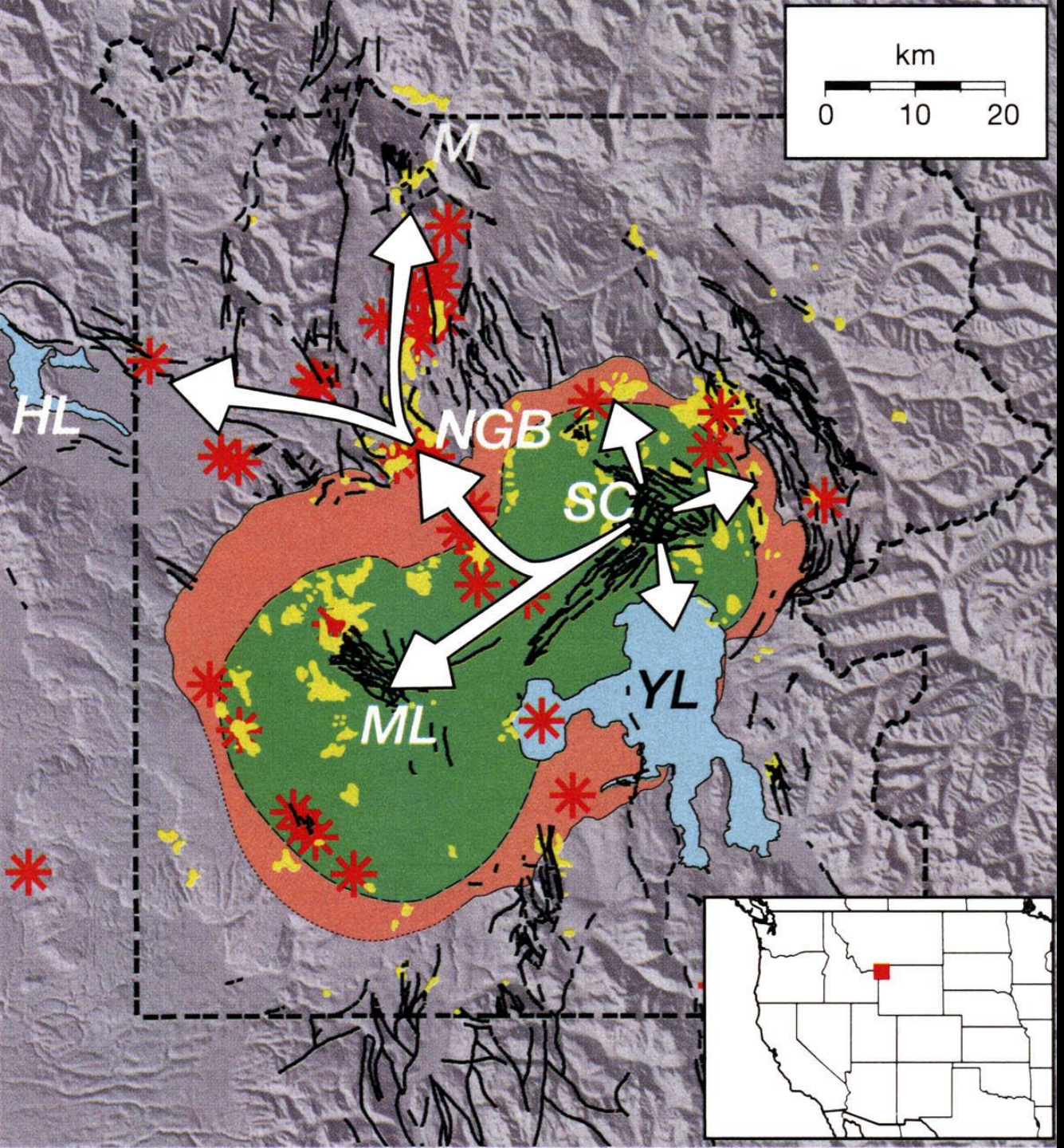


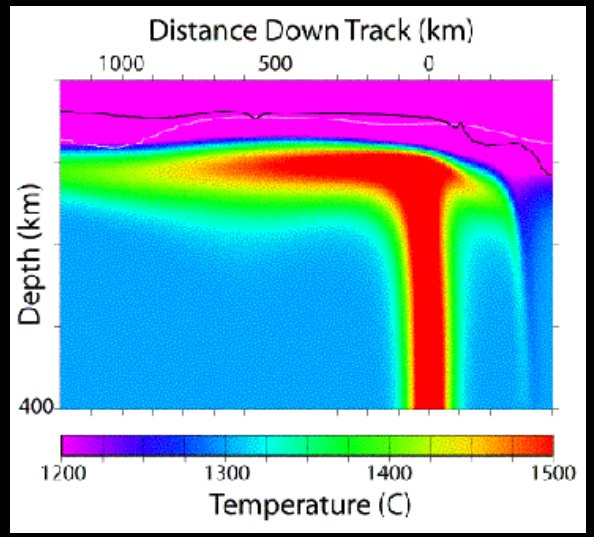
630,000 years ago to present

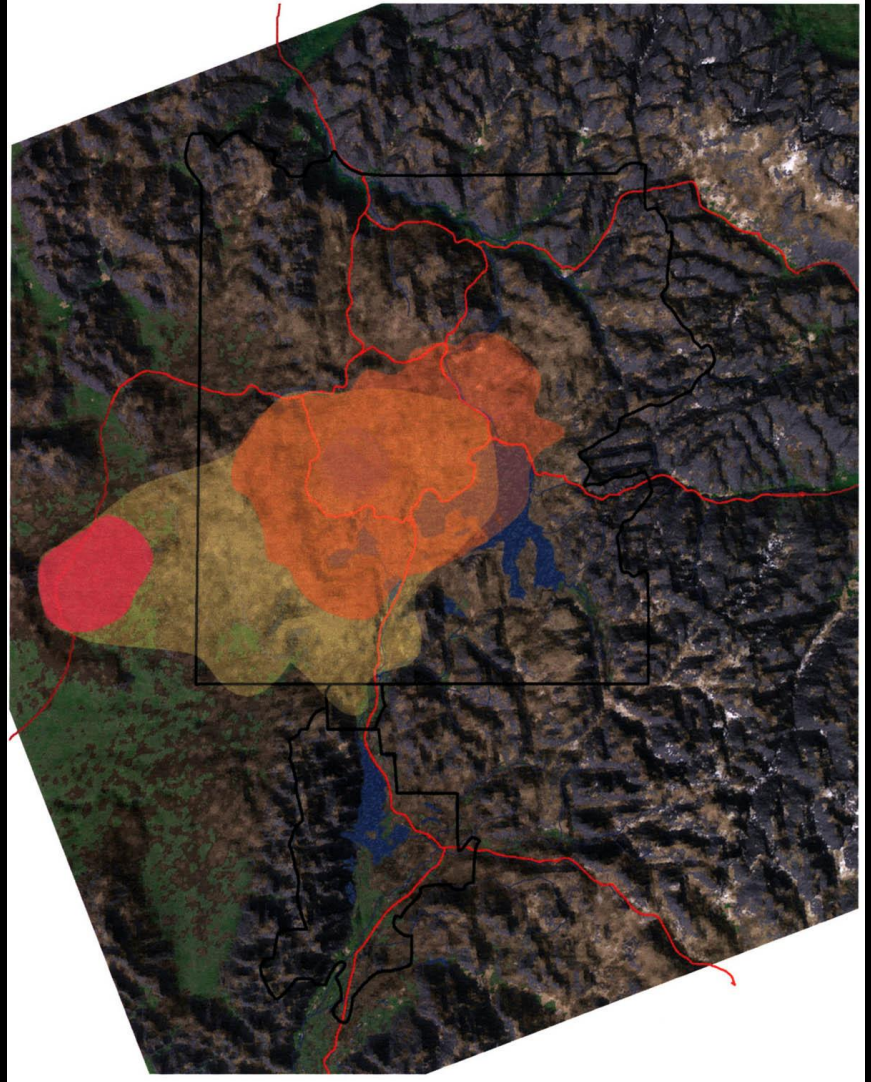



Giant
Yellowstone volcanic
eruption
SW
NE
Rocky
Mountains
Snake River Plain
"Old Yellowstones"
Basalt
Buried
calderas
Granite batholiths
Magma
chambers
Granite
Iron-rich remnants of magma chambers
Lower crust
Moho boundary
Rising melts
Hot upper mantle
Upper mantle melt
Yellowstone hotspot
Partially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


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


km
0
10
20
M
HL
NGB
SC
YL
ML


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



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.

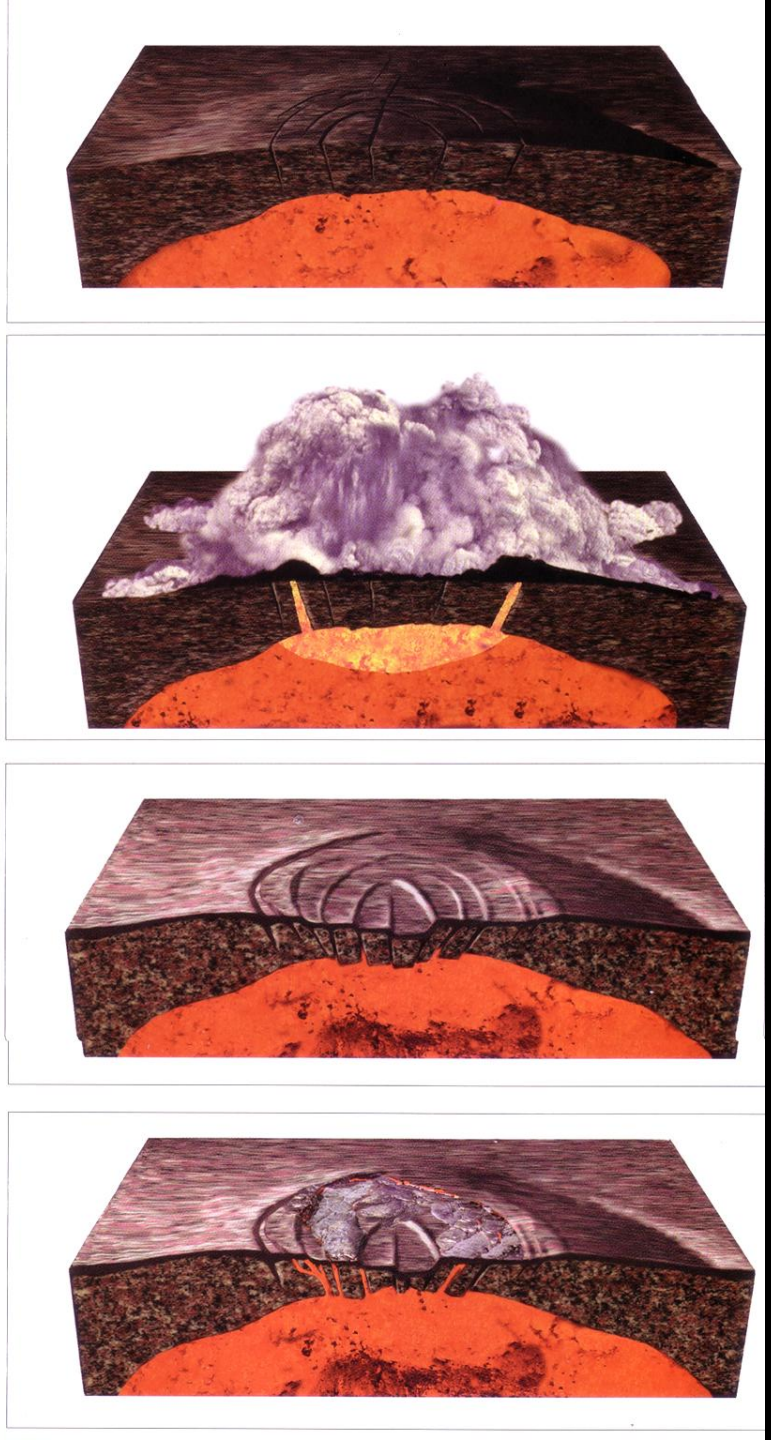
Three Eruptive Events

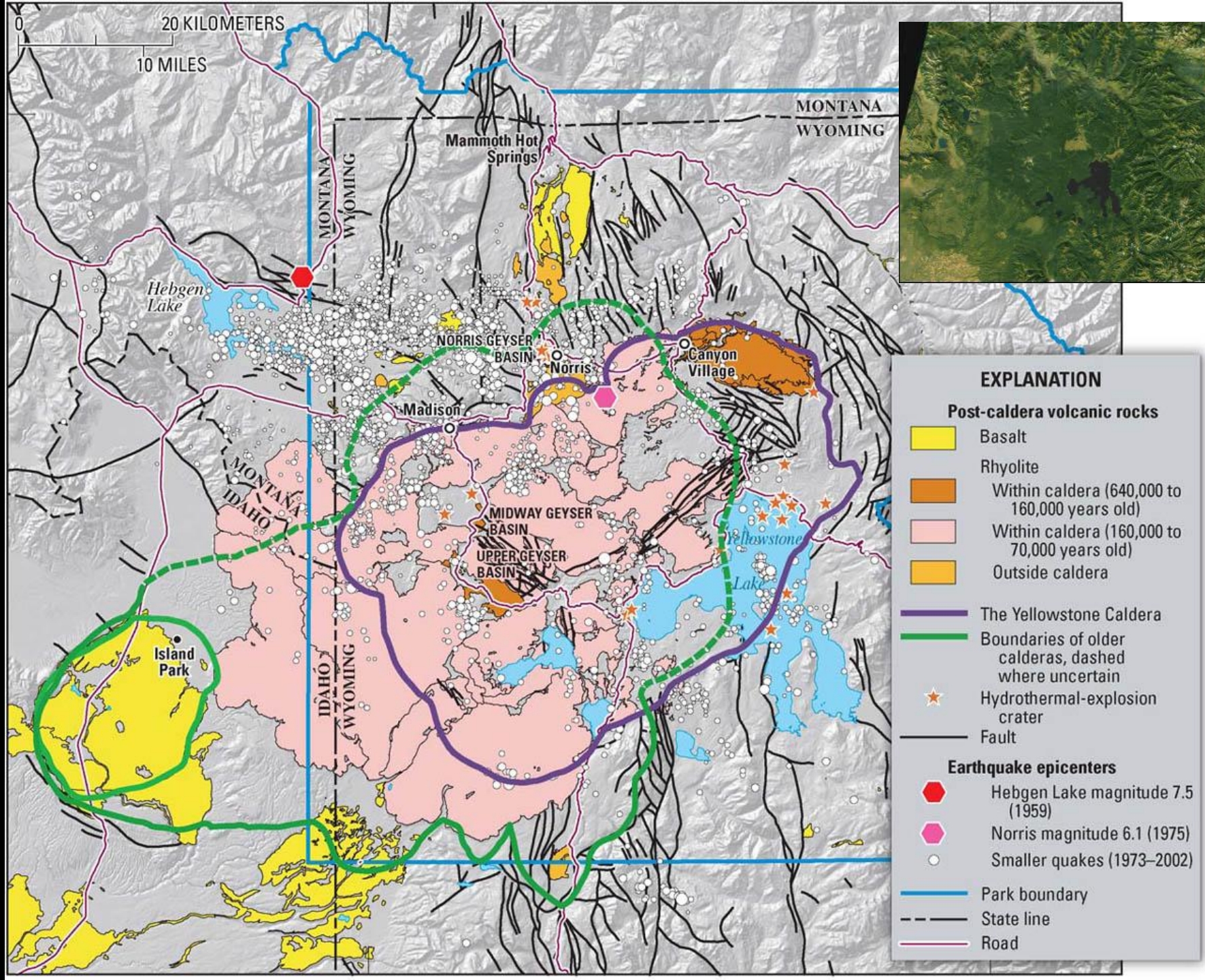
640 Ka – Lava Creek Caldera

1.3 Ma – Mesa Falls Caldera

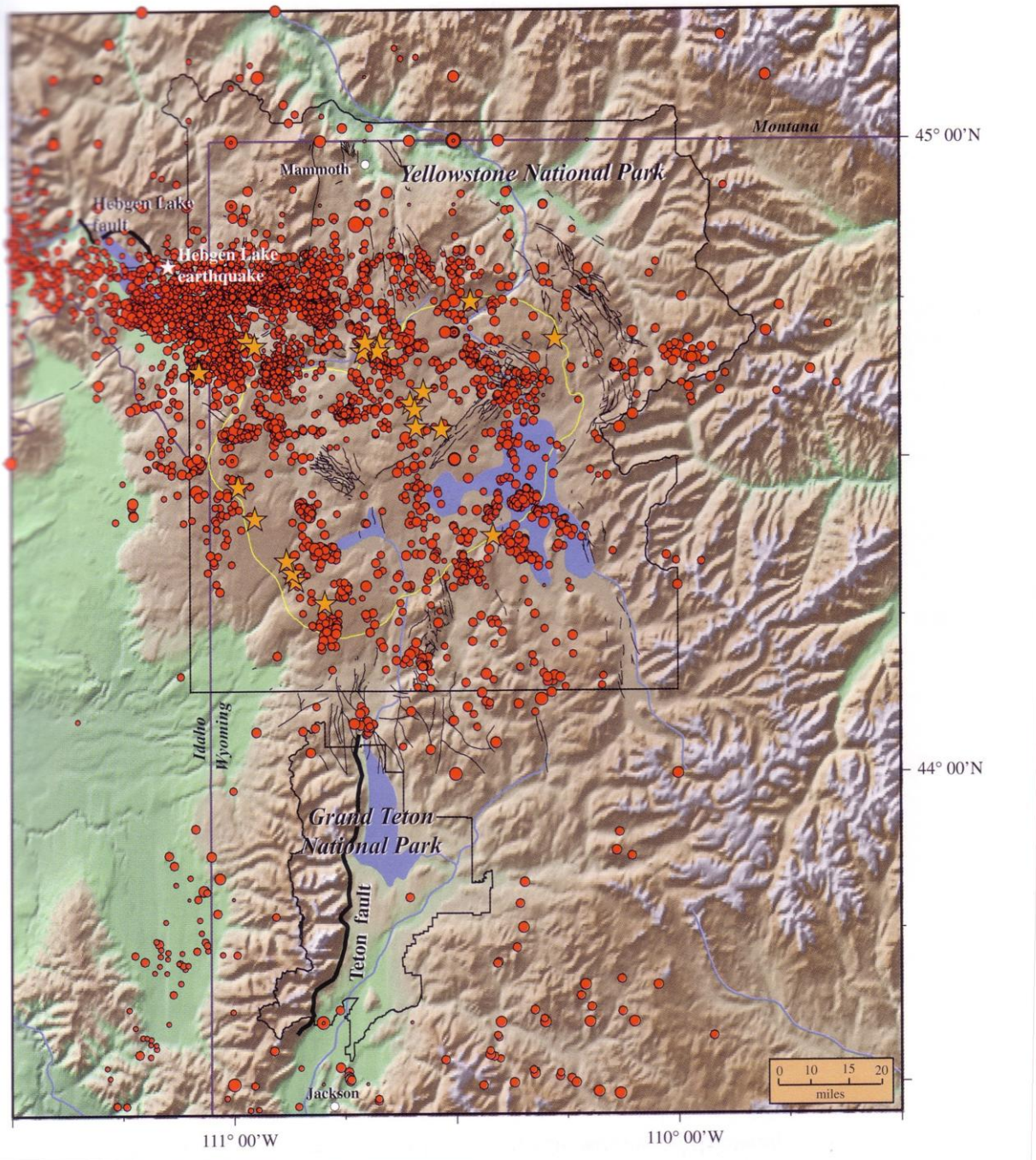
2.1 Ma – Huckleberry Ridge Caldera

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



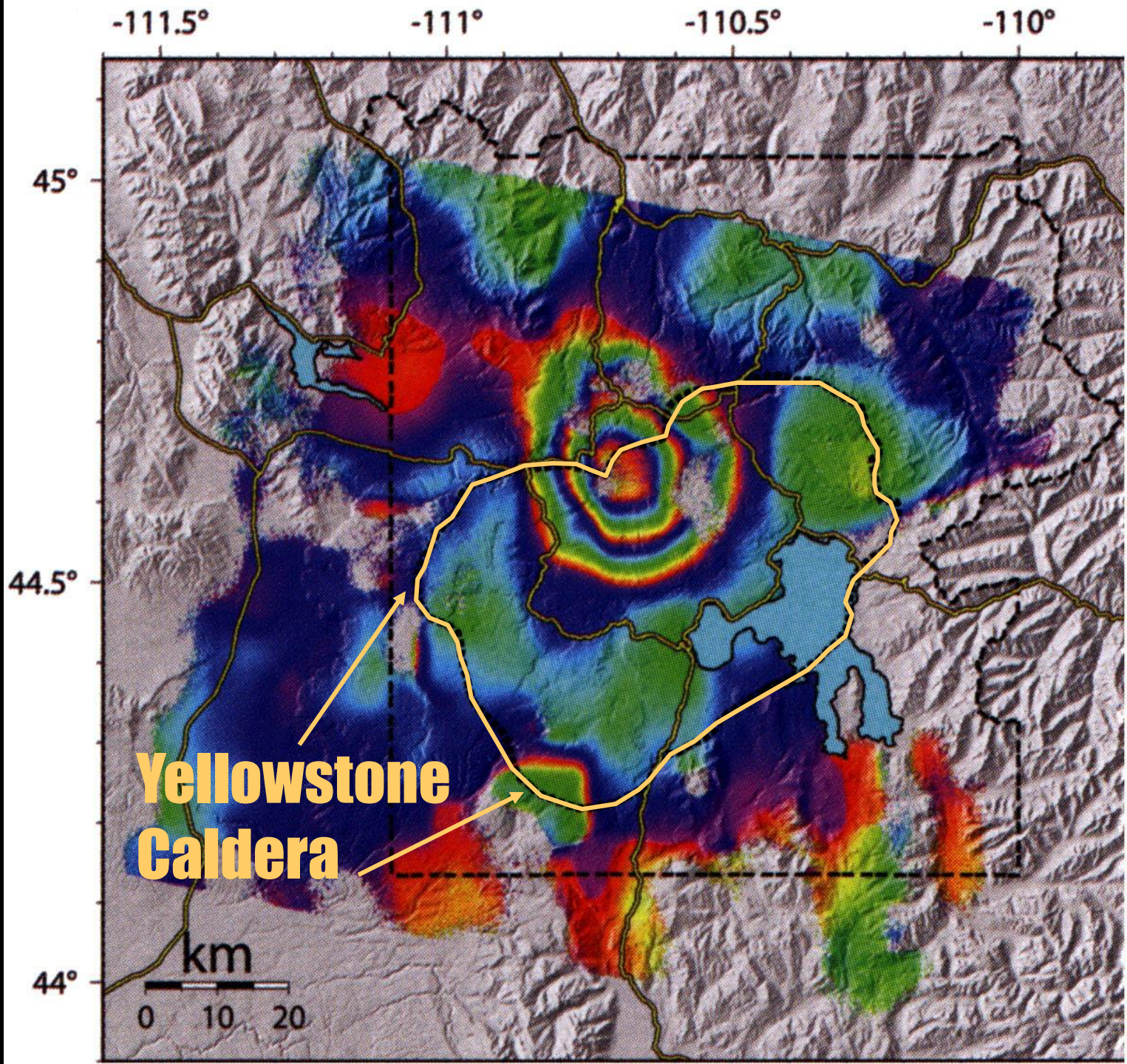
- Numerous Faults Cause Periodic Seismic Activity
- Earthquakes Vary in Magnitude but Most < M 5

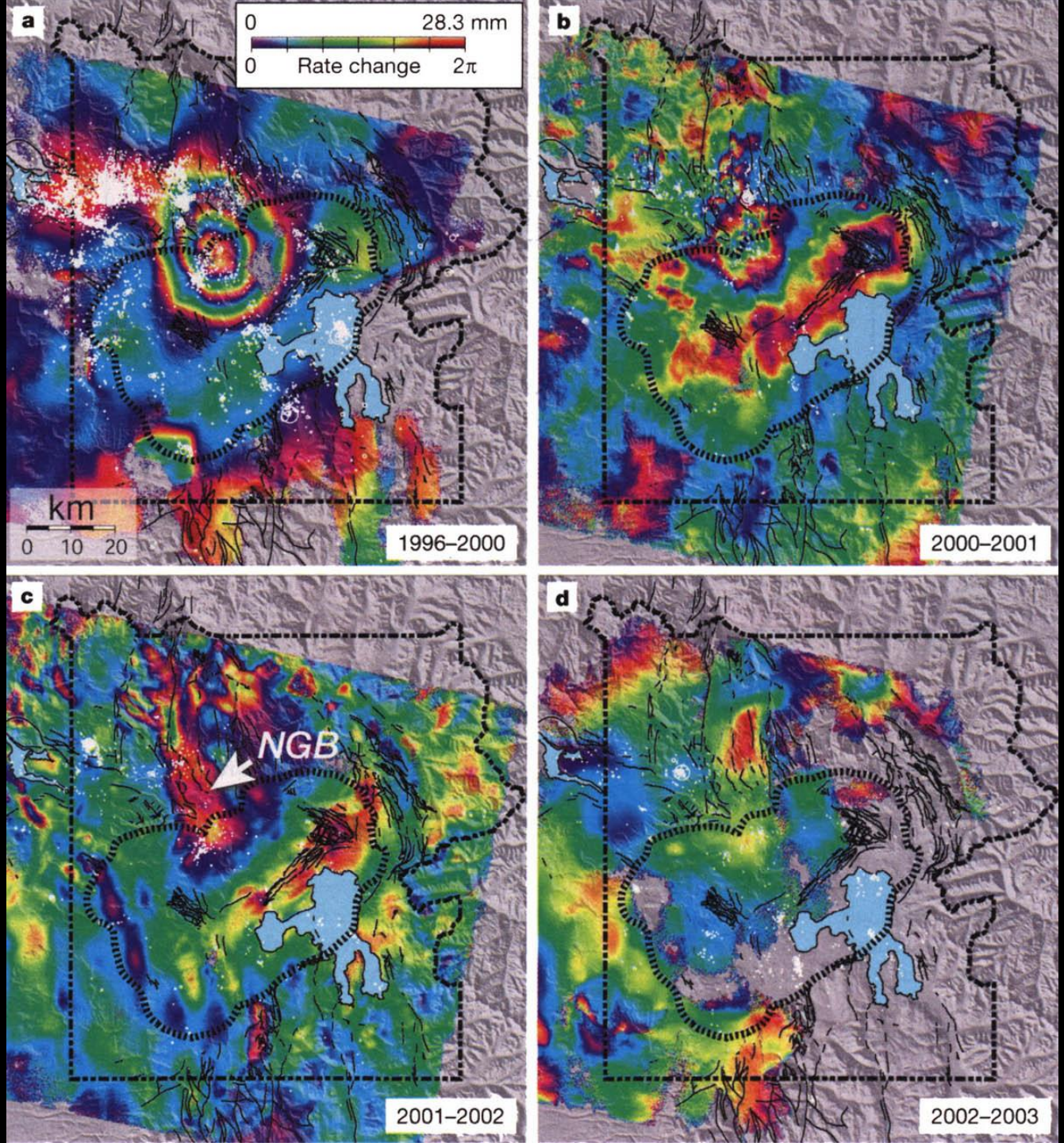
1996 – 2000

125 mm Uplift Centered at North Edge of Yellowstone Caldera

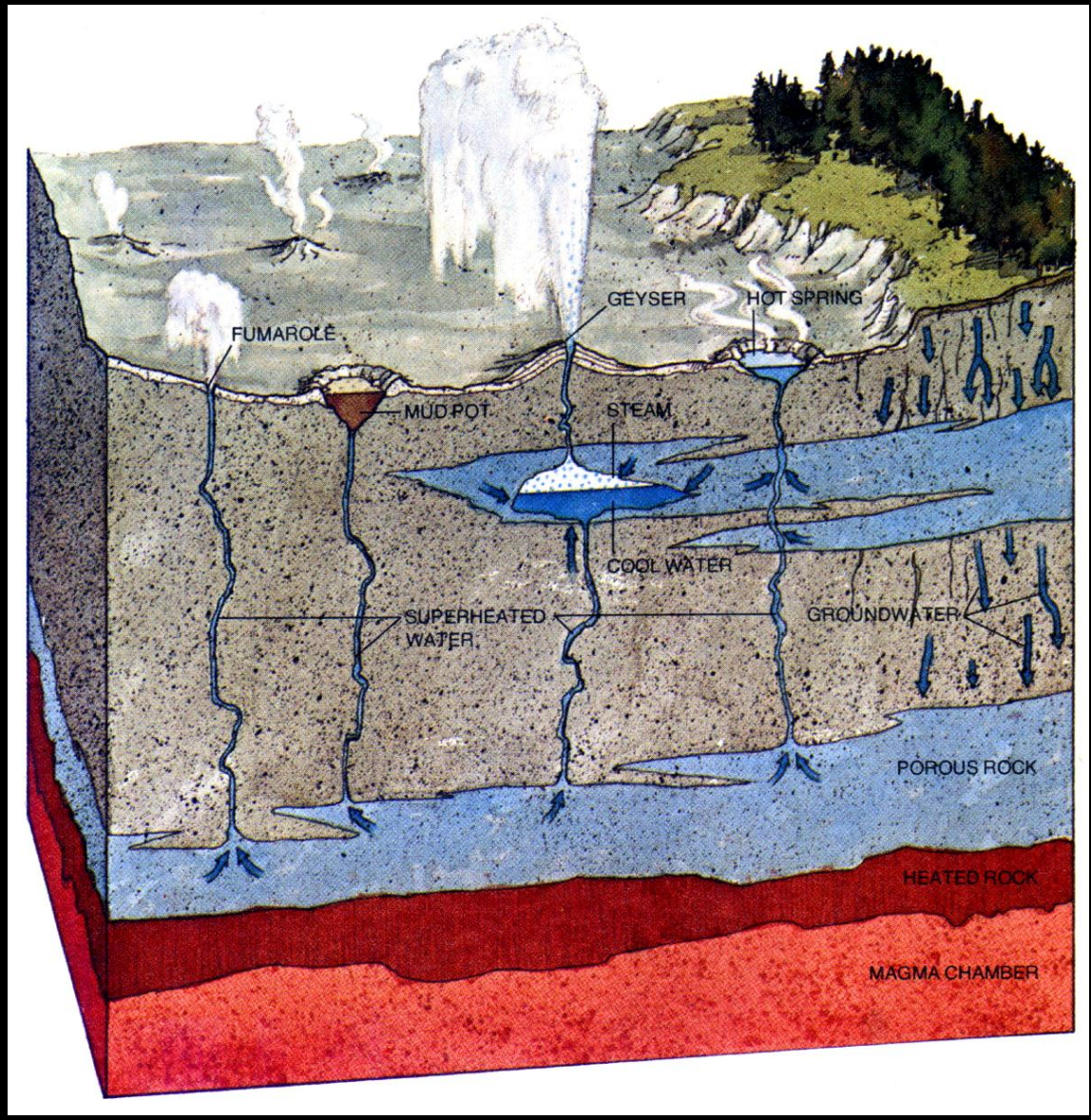
Each Spectra = 28 mm Uplift

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



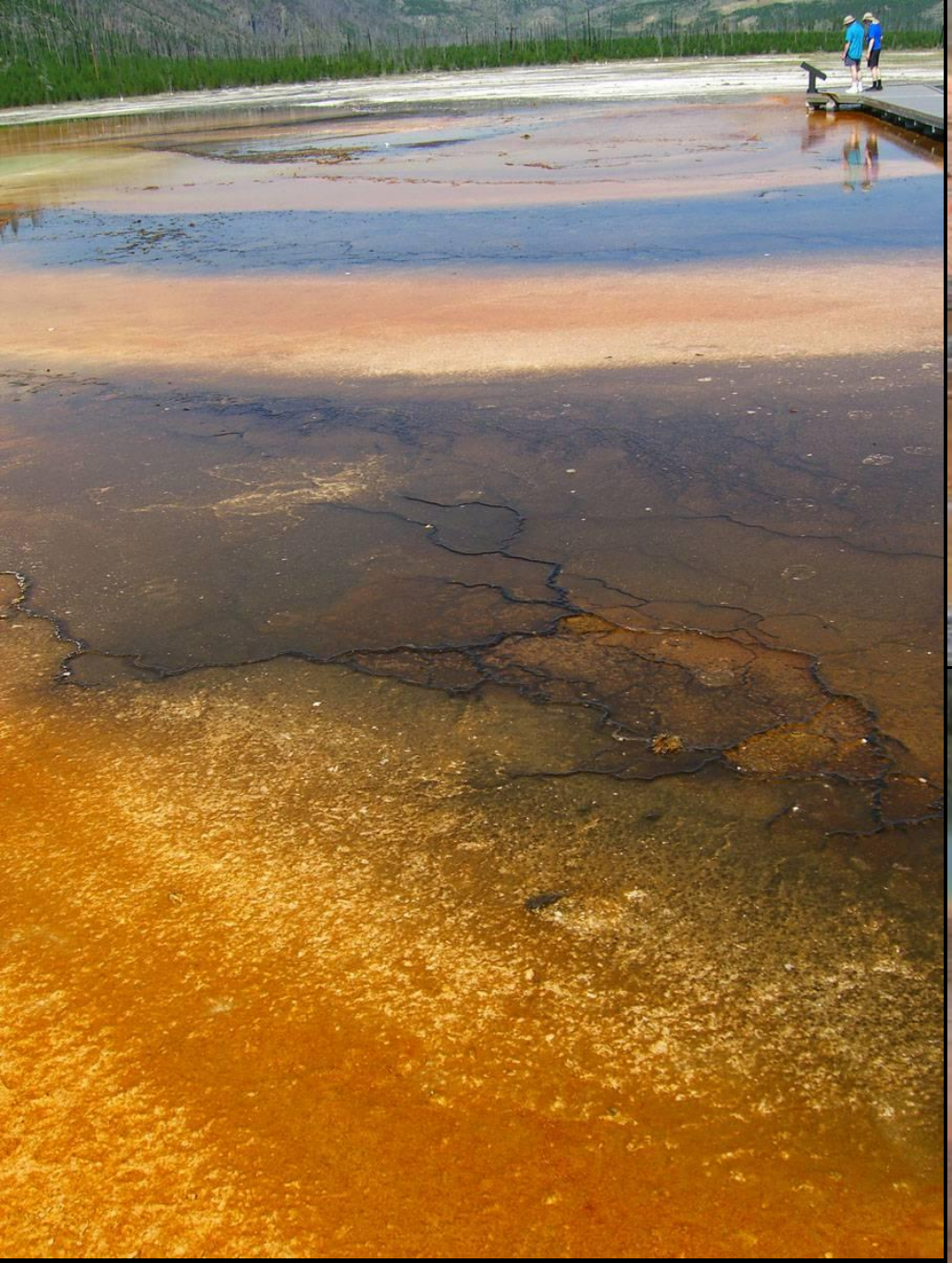
How Hot Springs Work

Grand Prismatic Spring

Grand Prismatic Spring

Grand Prismatic Spring


Grand Prismatic Spring



Grand Prismatic Spring





Chinese Spring

Churning Cauldron

Mammoth Hot Springs


Mammoth Hot Springs

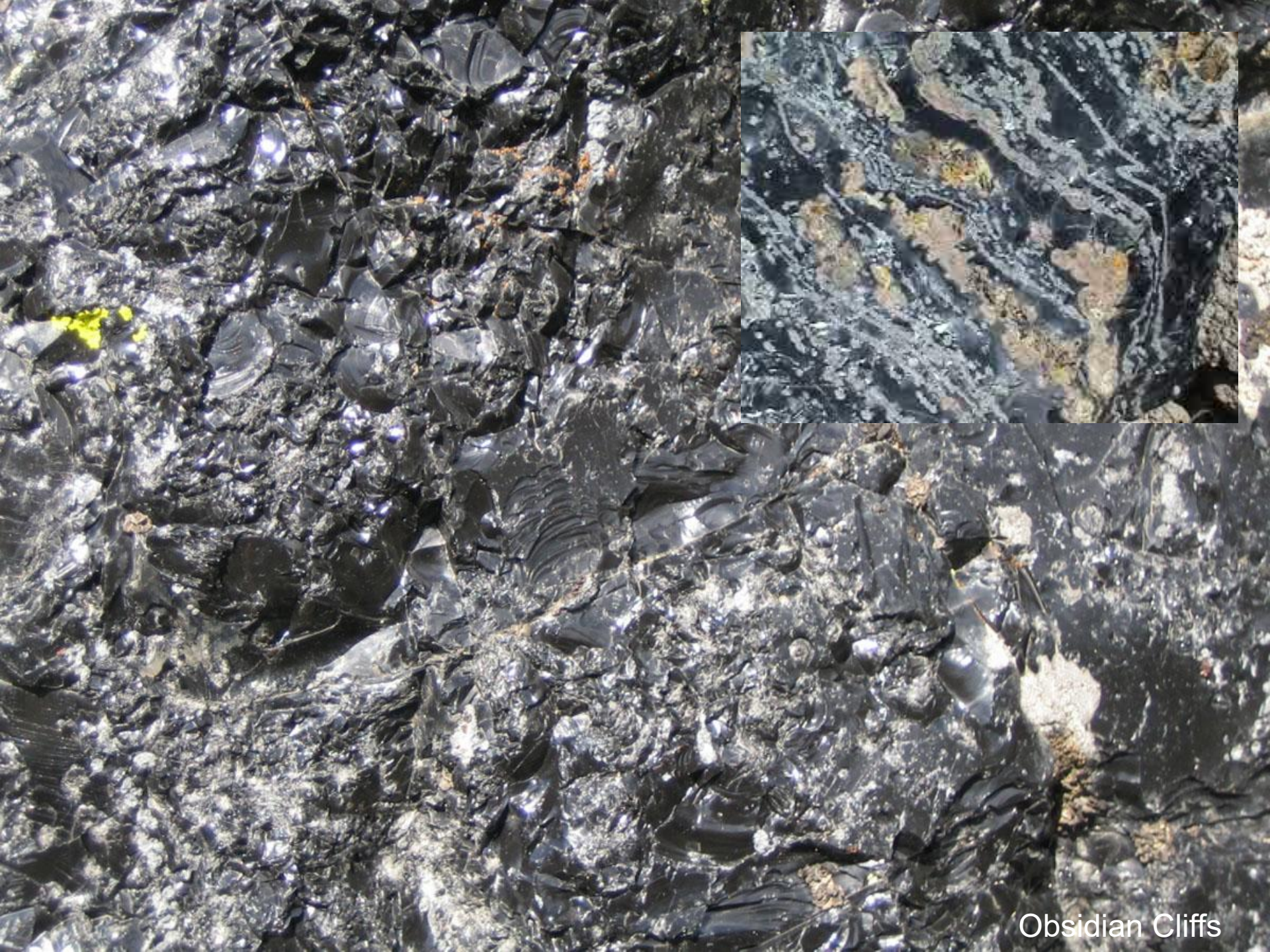

Mammoth Hot Springs

Mammoth Hot Springs


Obsidian Cliffs

Obsidian Cliffs

Obsidian Cliffs



Obsidian Cliffs

Grand Canyon of the Yellowstone River

Hofstra University
Geology 280F
23 July – 02 August 2007

Now – You Are Eggsperts at Wyoming Geology

Geological Wonders of Yellowstone National Park, Wyoming

New York Mineral Show
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