Cascadia EarthScope Earthquake and Tsunami Education Program (CEETEP)

Aberdeen, Washington Workshop

August 11-14, 2014

Beauty and the Beast: Plate Tectonics and Geological Hazards of the Pacific Northwest

Bob Lillie

Certified Interpretive Trainer

Emeritus Professor of Geosciences

Oregon State University

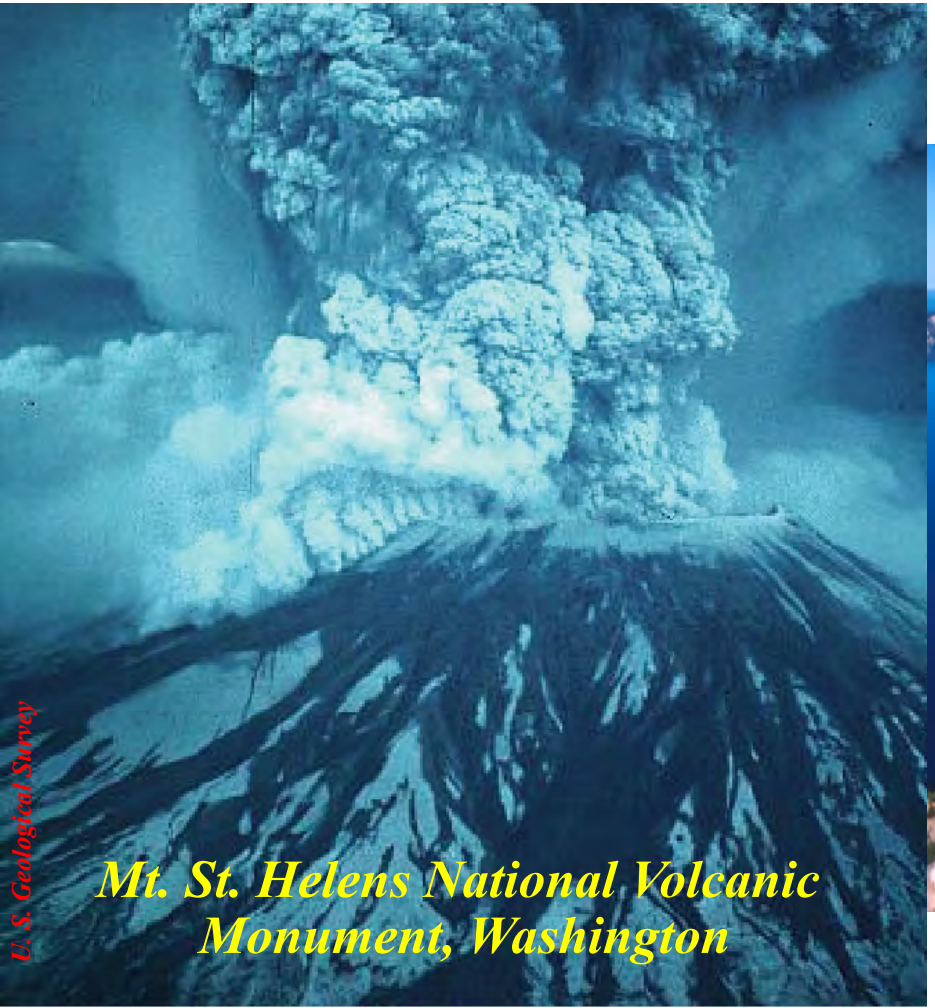
www.robertjlillie.com

Niawiakum River, Washington

Robert J. Lillie

Beauty and the Beast

"The same geological forces that threaten our lives with earthquakes, tsunamis, and volcanic eruptions also nourish our spirits by creating the spectacular mountains, valleys, and coastlines of the Pacific Northwest."



U. S. Geological Survey

Mt. St. Helens National Volcanic Monument, Washington

Robert J. Lillie

Crater Lake National Park, Oregon

Coastal Ranges

Most of the People

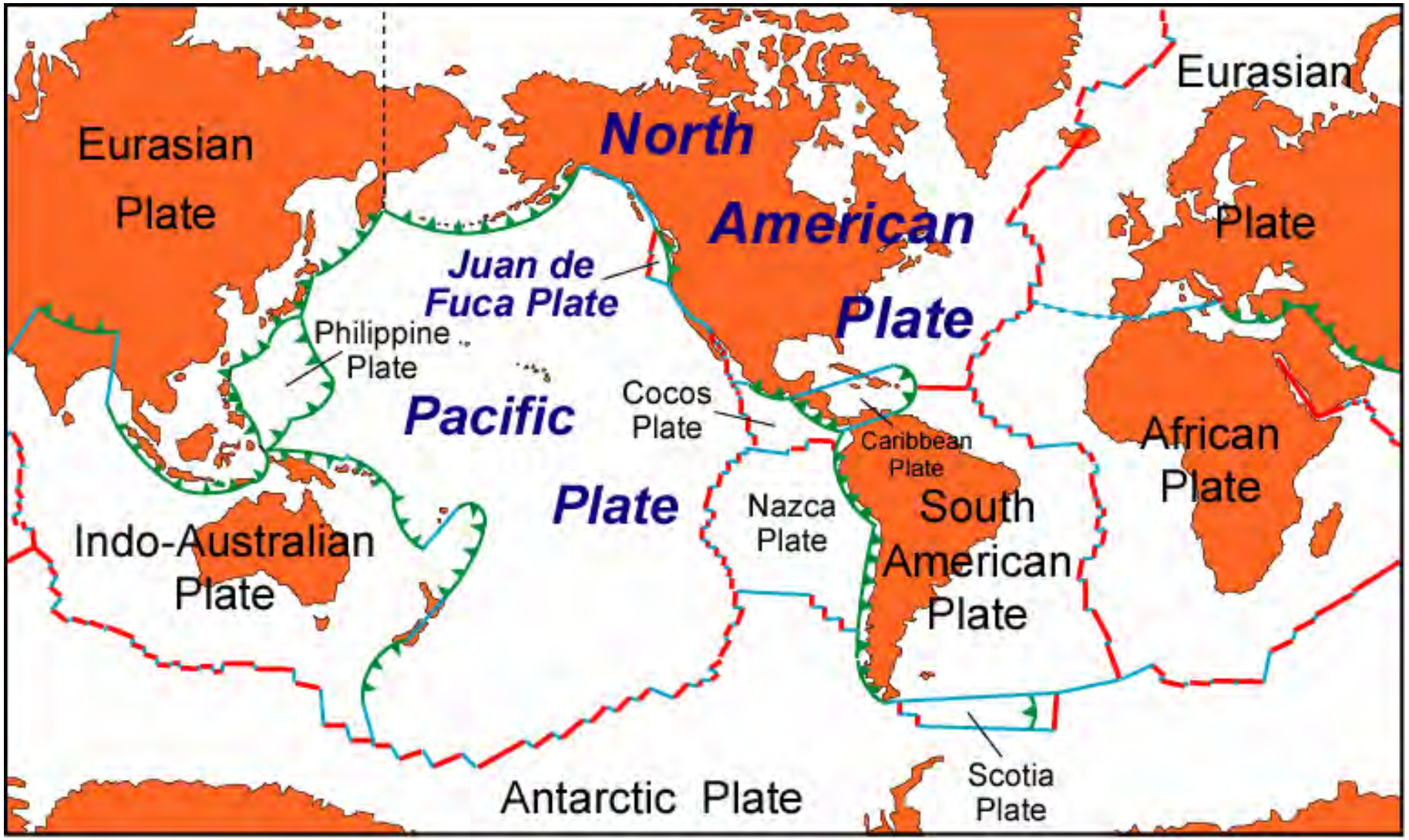
1. Why are there two parallel mountain ranges in the Pacific Northwest?

2. Why are there earthquakes, tsunamis and volcanic eruptions?

Cascade Volcanoes

National Park Lands in the Pacific Northwest

Activities: Binder p. 69 – "World Map of Plate Boundaries"



Cracked Egg Shell!

Activities: Binder p. 69 – "World Map of Plate Boundaries"

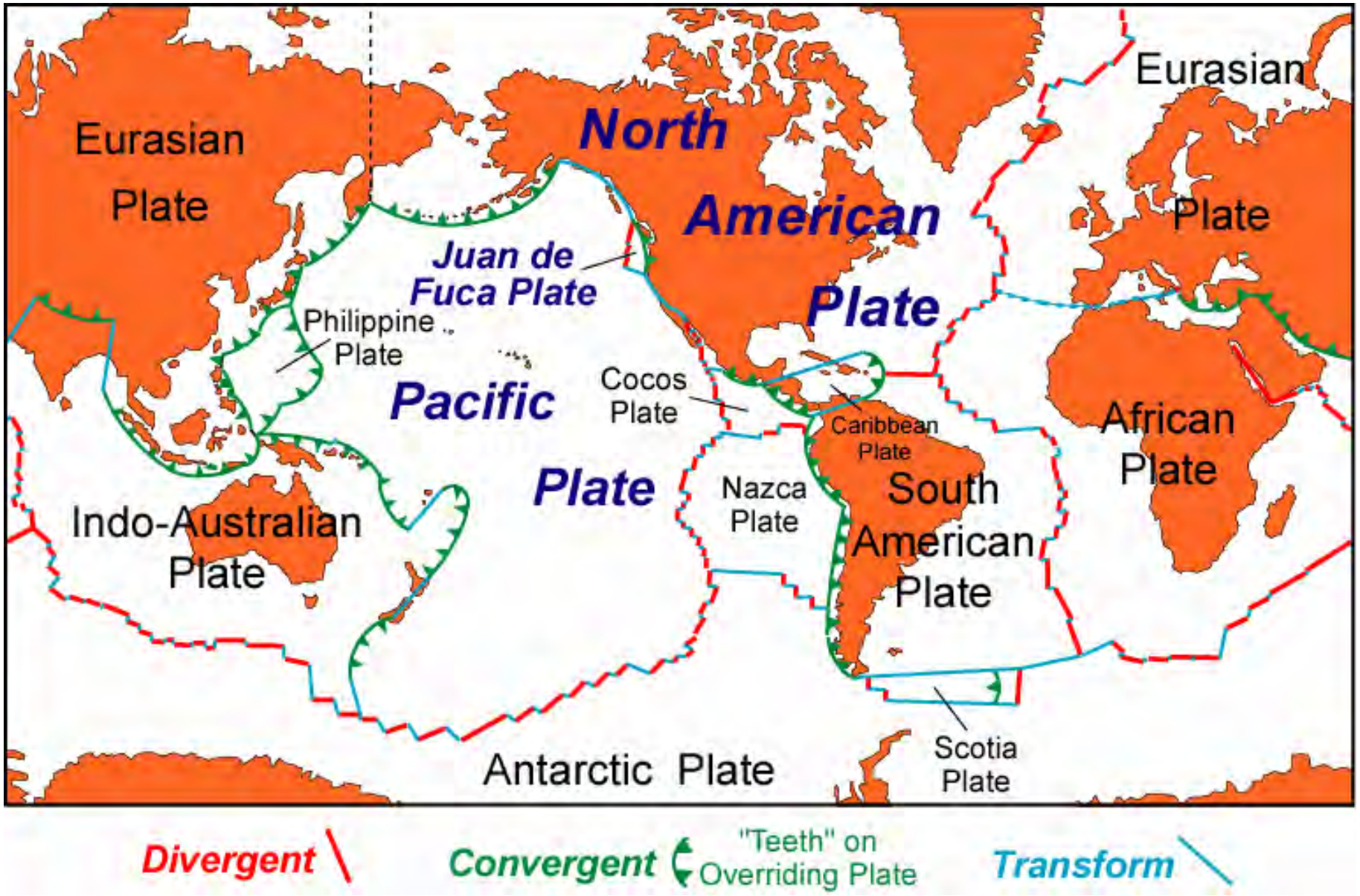


Plate Boundaries

Plate Tectonics: Mountain Ranges

Most mountain ranges—both onshore and offshore—occur along the boundaries of moving plates.

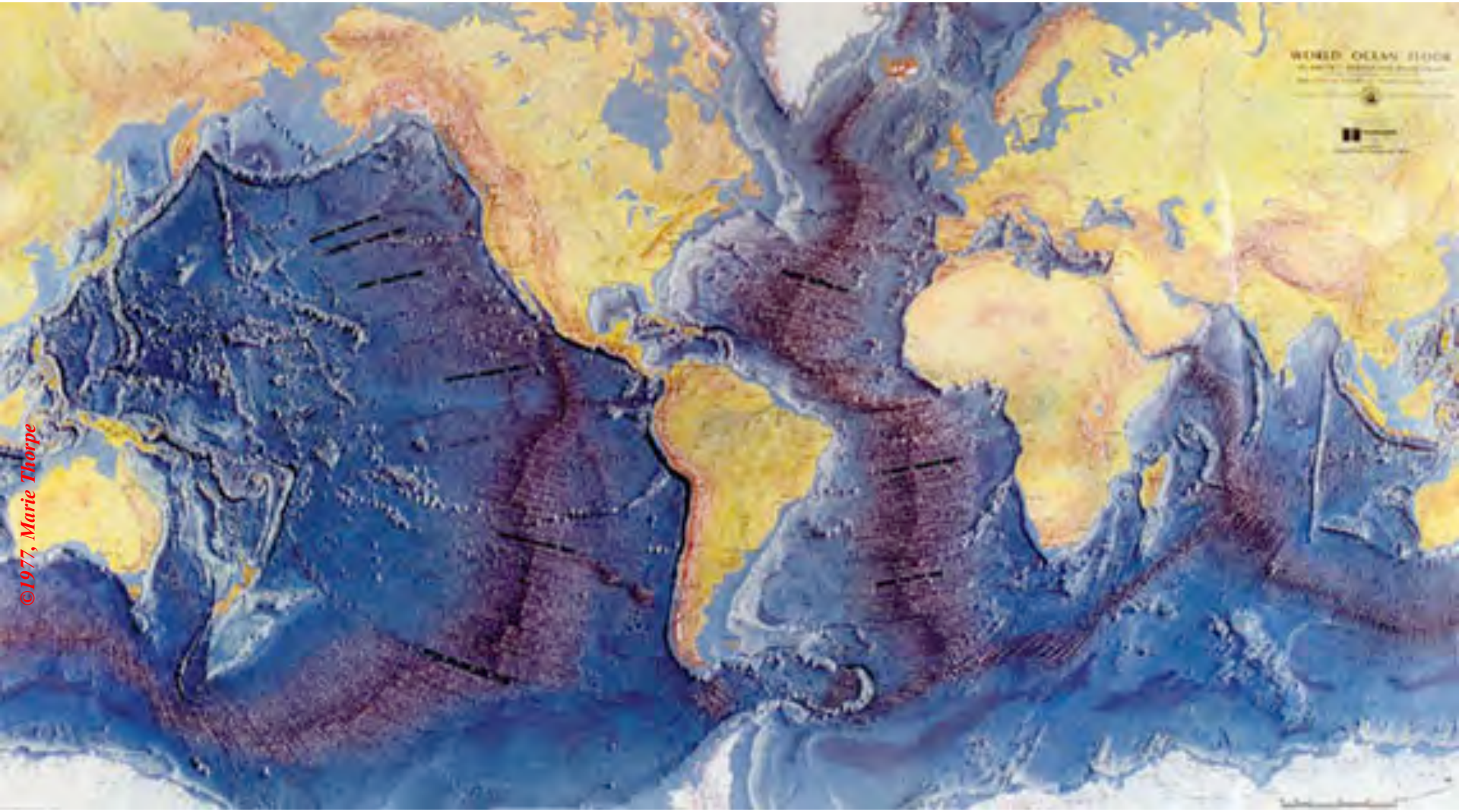
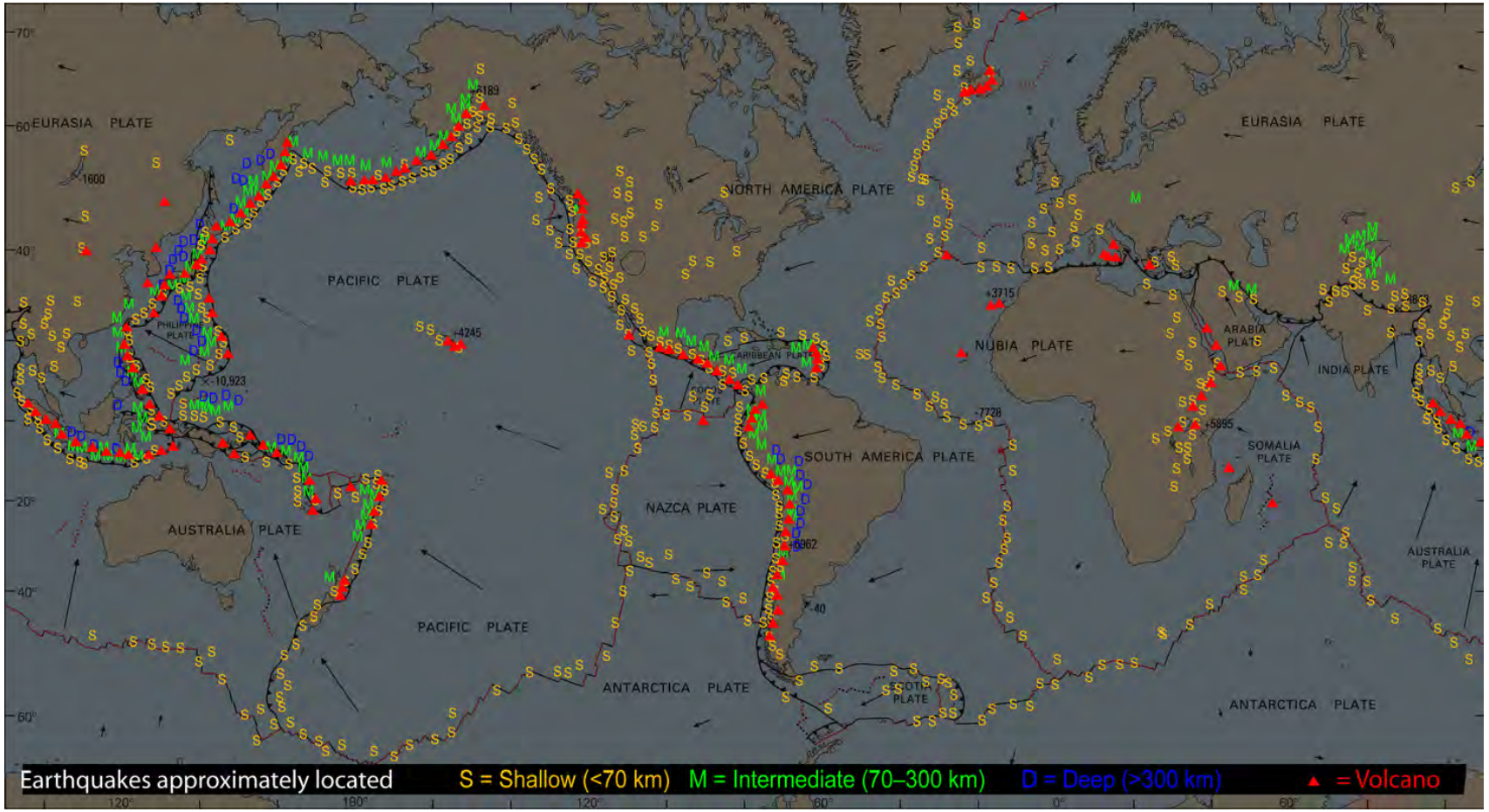


Plate Tectonics: Earthquakes and Volcanoes

- Most volcanoes and earthquakes occur along plate boundaries.
- The deeper quakes (green and blue) occur where one plate dives beneath another (subduction zones).
- Pacific "Ring of Fire"

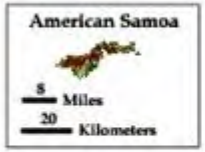


Modified from USGS Graphics and Lillie, 2005, "Parks and Plates"

NATIONAL PARKLANDS

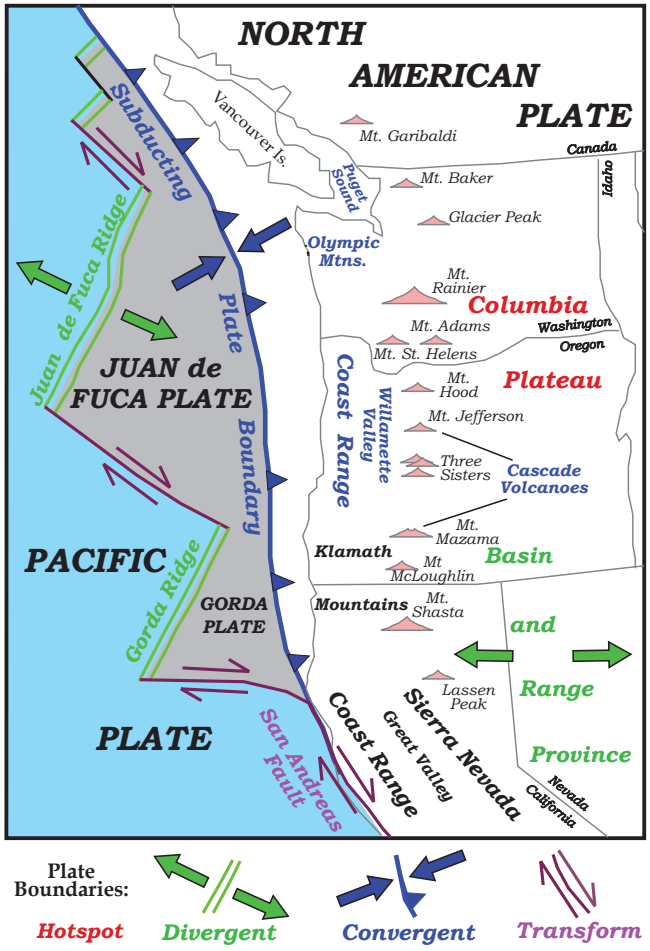
What forms the spectacular landscapes of the Pacific Northwest?

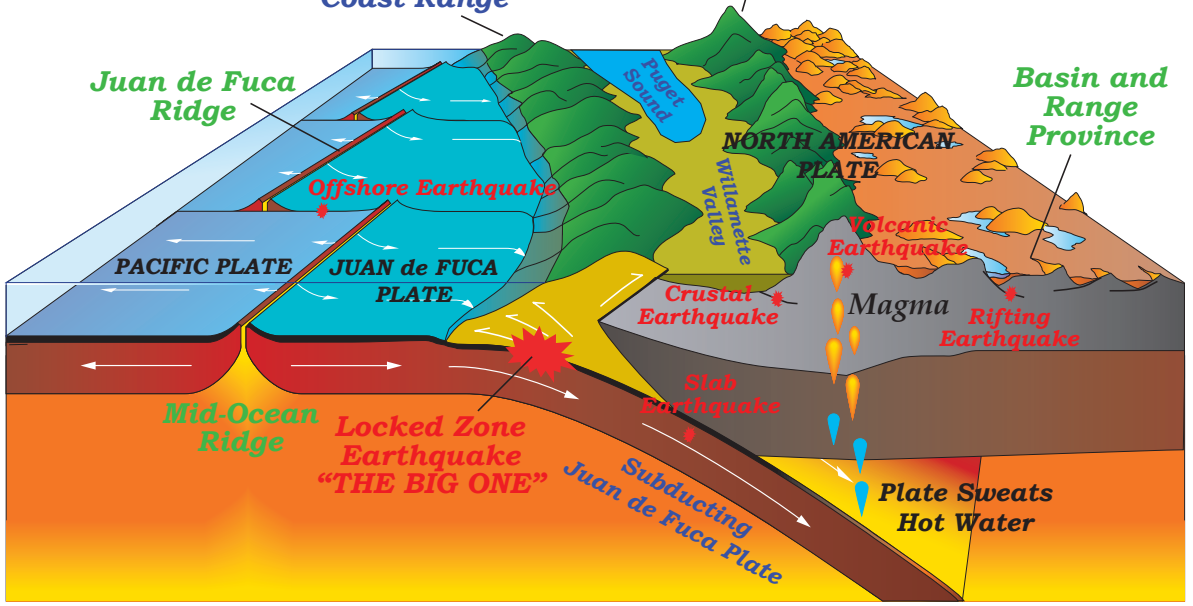
Why are there earthquakes, tsunamis, and volcanic eruptions?



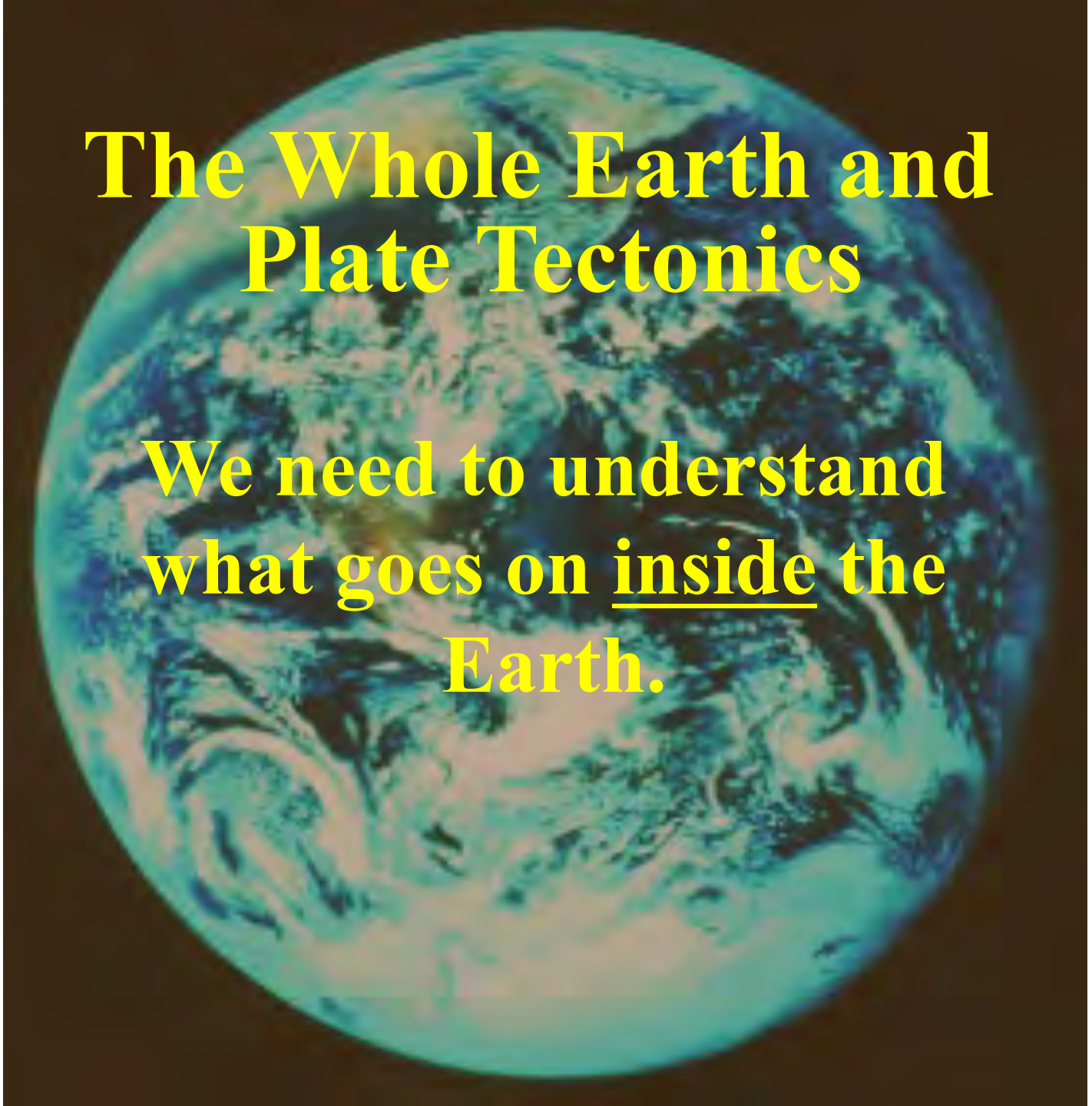
Activities: Binder Foldout – "CEETEP Poster"

Plate Tectonics of the Pacific Northwest





Cascadia EarthScope Earthquake and Tsunami Education Program
http://ceetep.oregonstate.edu

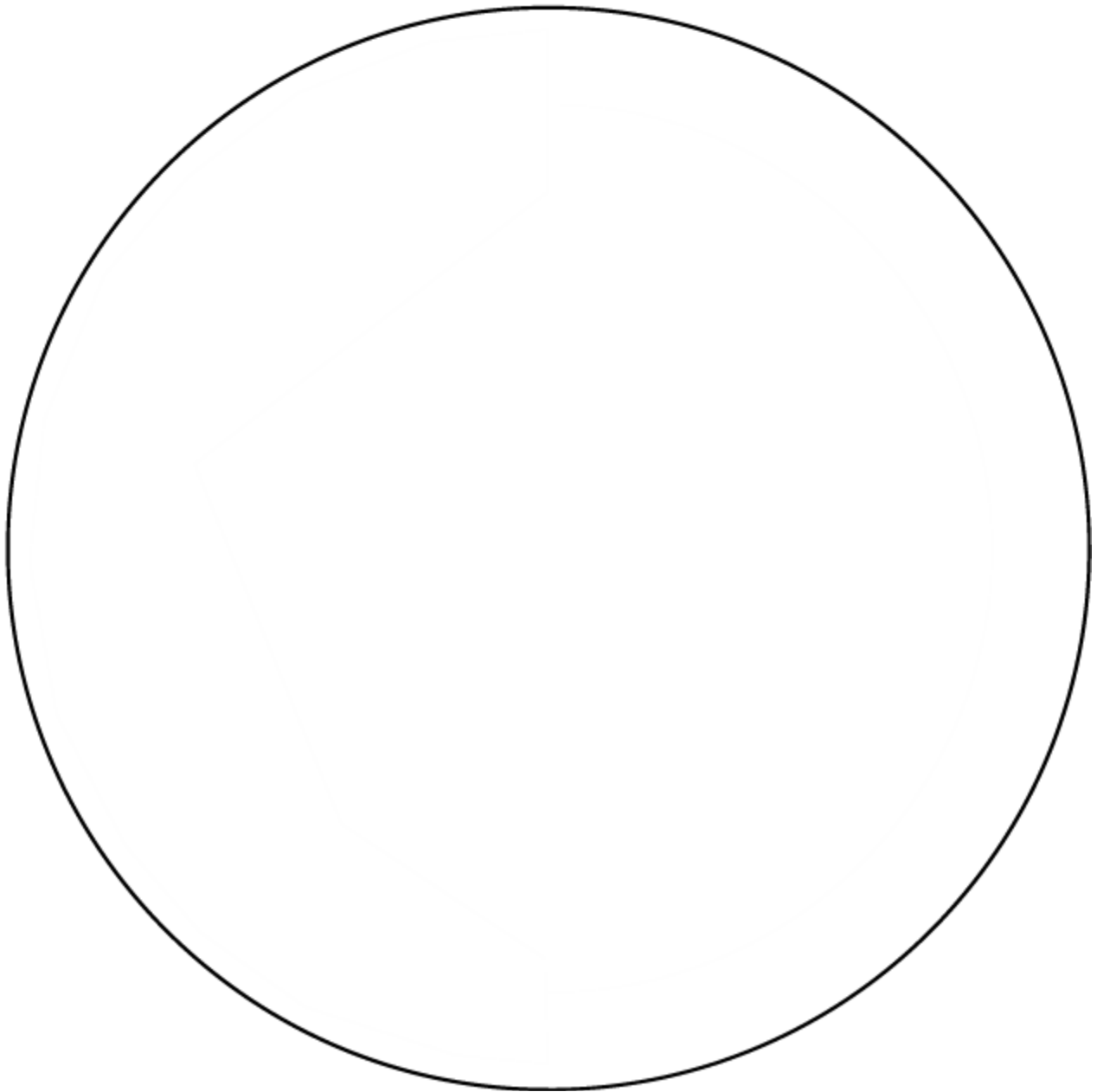


The Whole Earth and Plate Tectonics

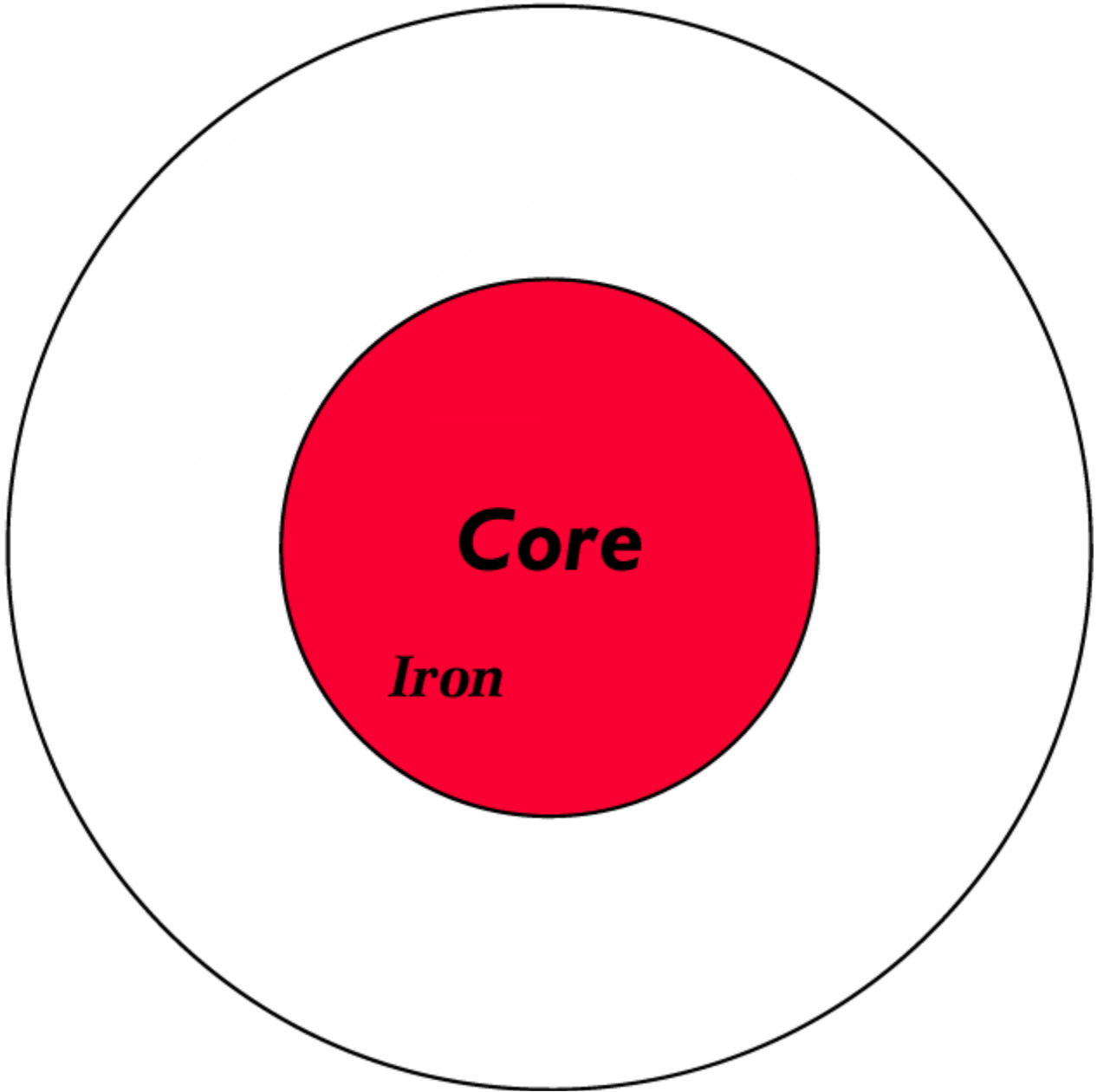
We need to understand what goes on inside the Earth.

National Aeronautics and Space Administration

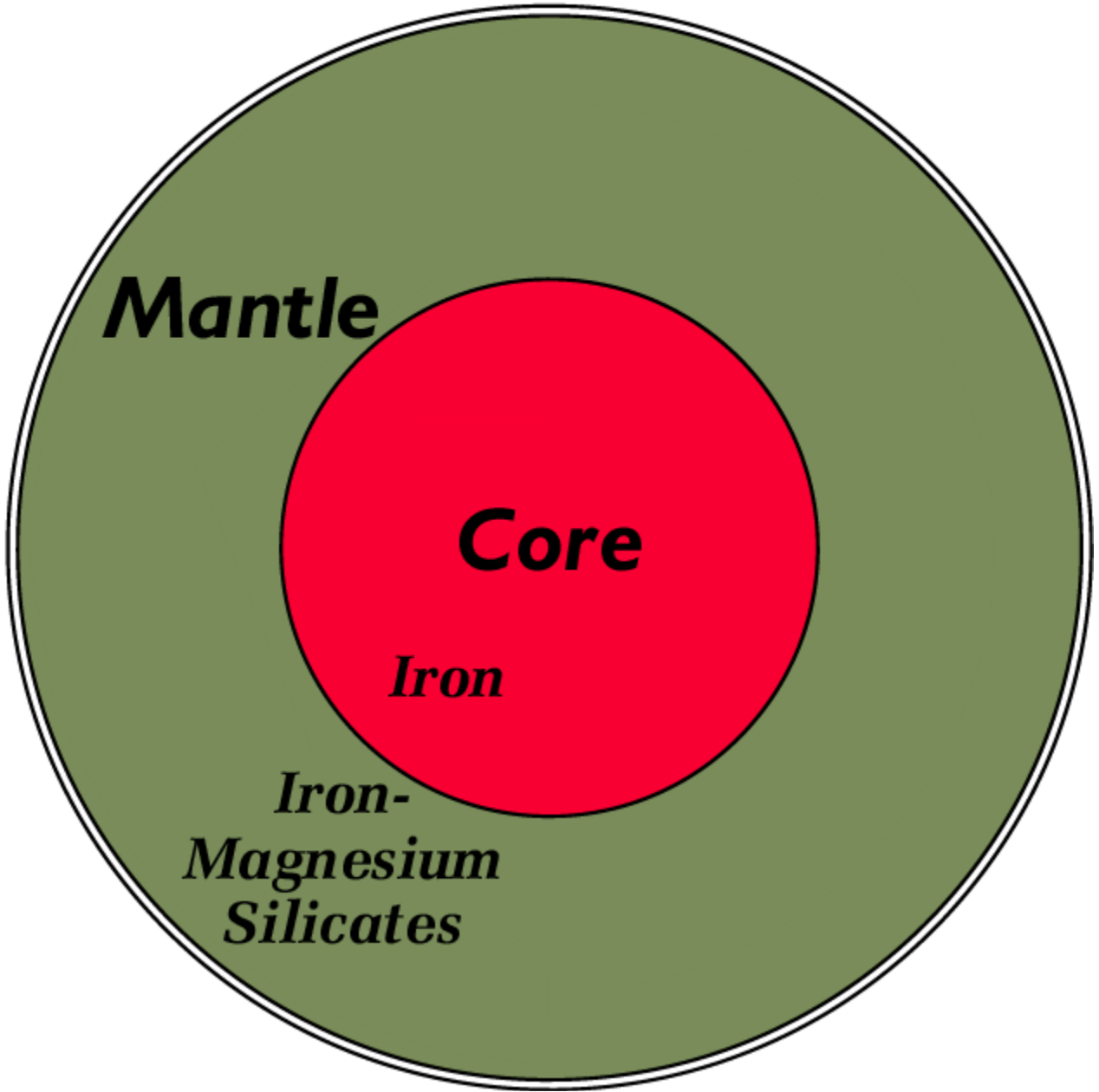
Classical Divisions of the Earth
(Chemical Composition)



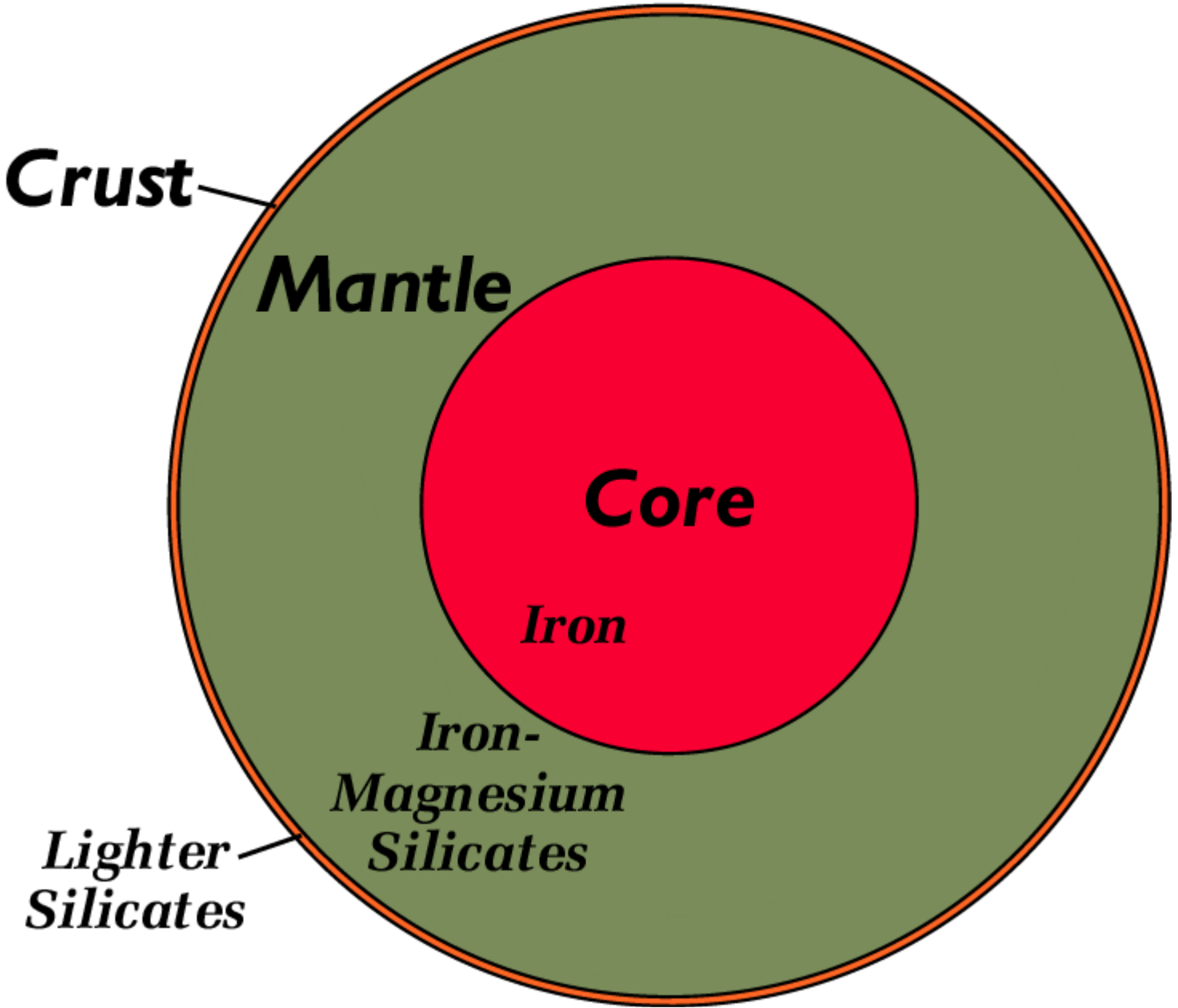
Classical Divisions of the Earth
(Chemical Composition)

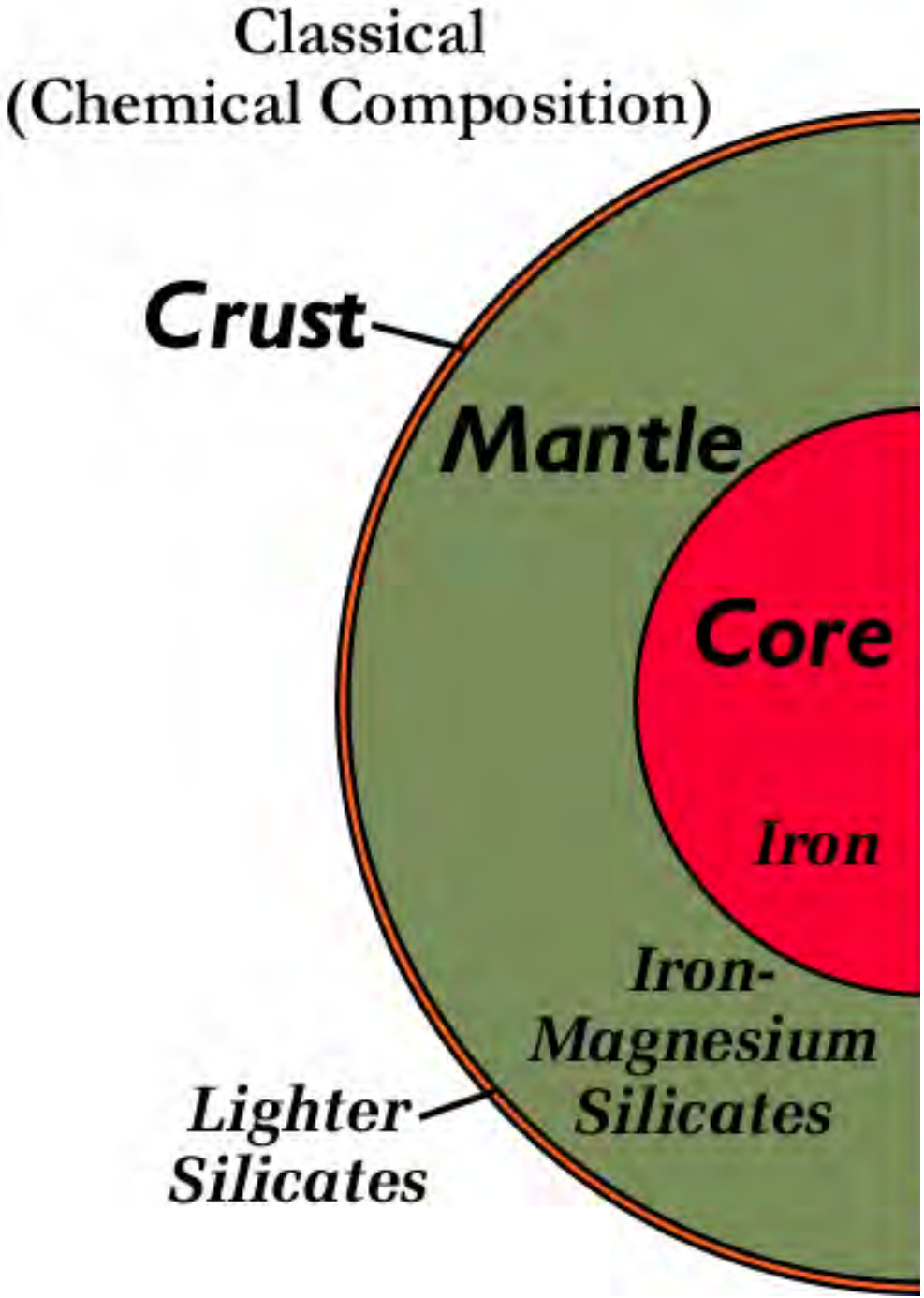


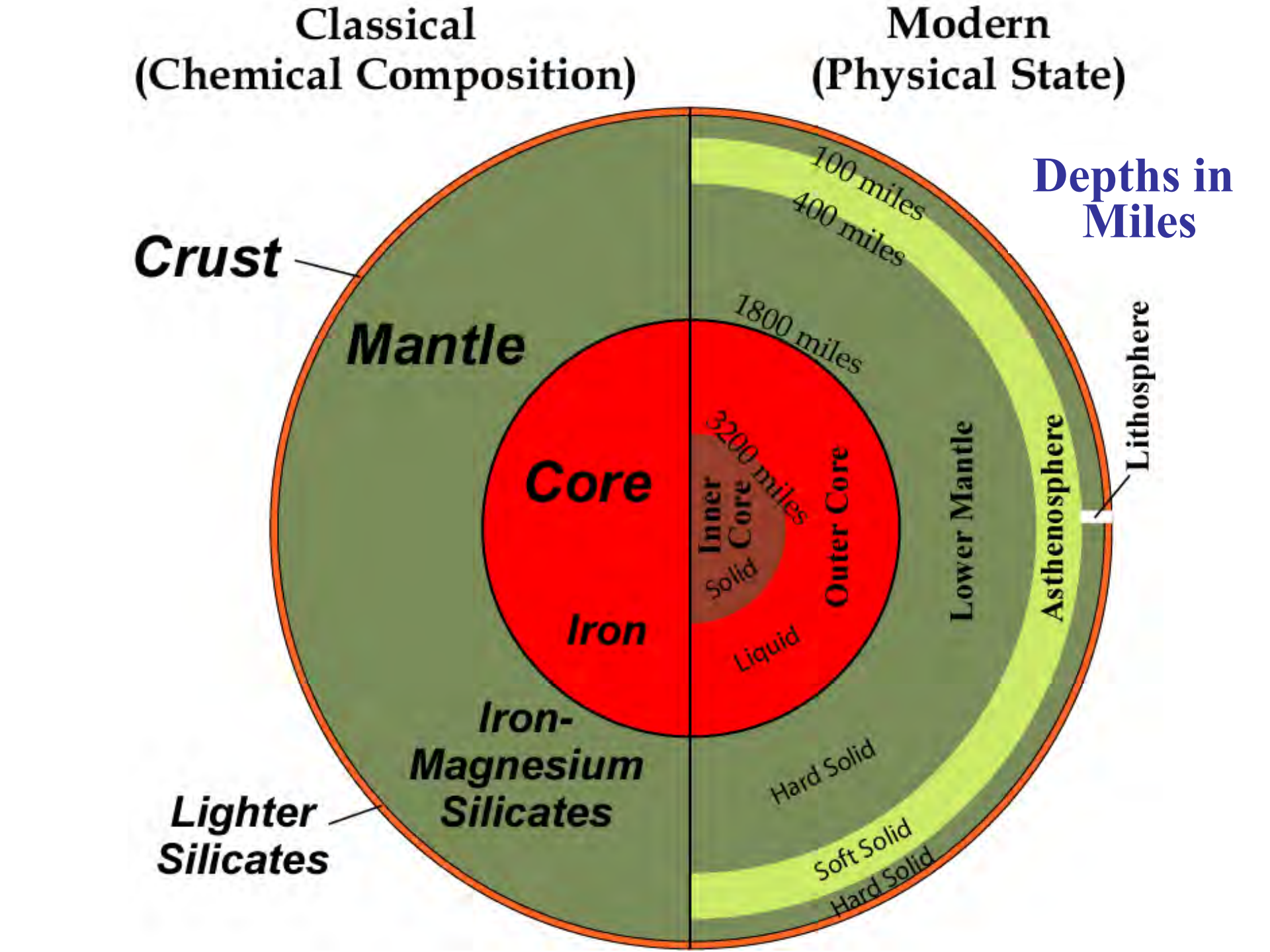
Classical Divisions of the Earth (Chemical Composition)



Classical Divisions of the Earth (Chemical Composition)



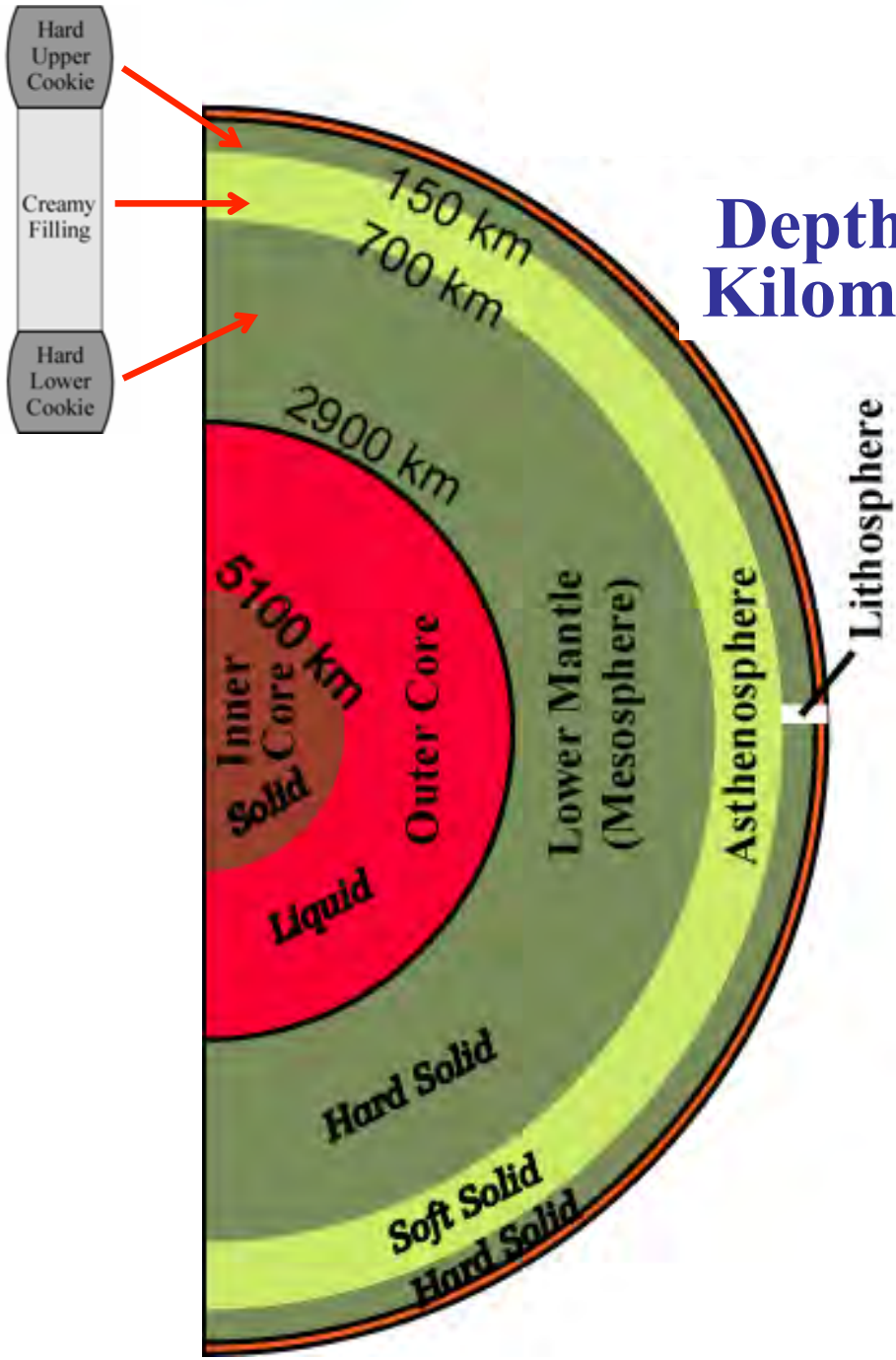

Classical
(Chemical Composition)
Crust
Mantle
Core
Iron
Iron-
Magnesium
Silicates
Lighter
Silicates


Classical
(Chemical Composition)
Modern
(Physical State)
Depths in Miles
Crust
Mantle
Core
Iron
Iron-
Magnesium
Silicates
Lighter
Silicates
100 miles
400 miles
1800 miles
3200 miles
Inner Core
Solid
Outer Core
Liquid
Lower Mantle
Asthenosphere
Lithosphere
Hard Solid
Soft Solid
Hard Solid

Activities:

“Oreo Cookie Tectonics”

Oreo® Cookie



Oreo® Cookie

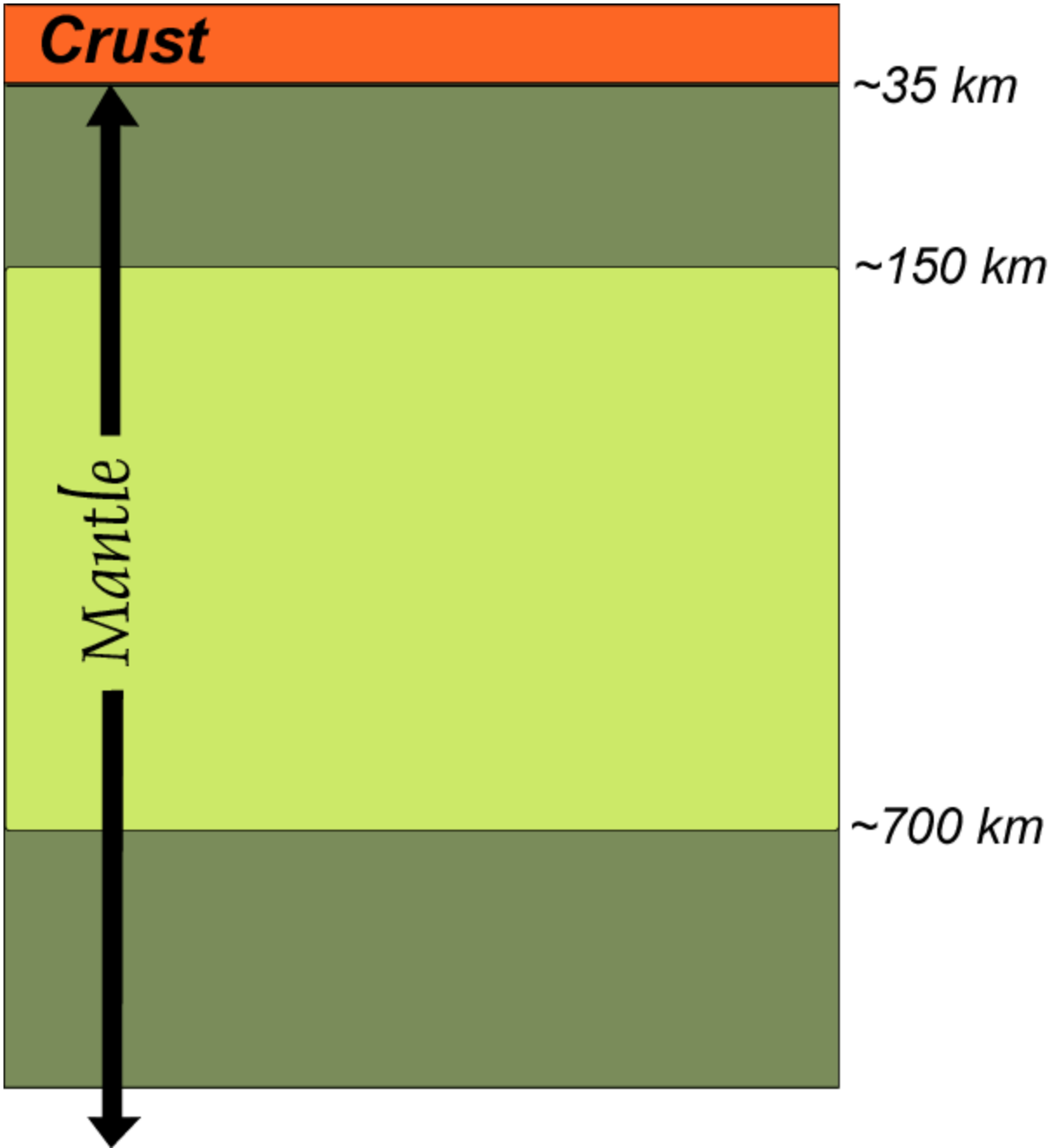
Oreo® Cookie


Hard
Upper
Cookie
Creamy
Filling
Hard
Lower
Cookie


Crust
~35 km

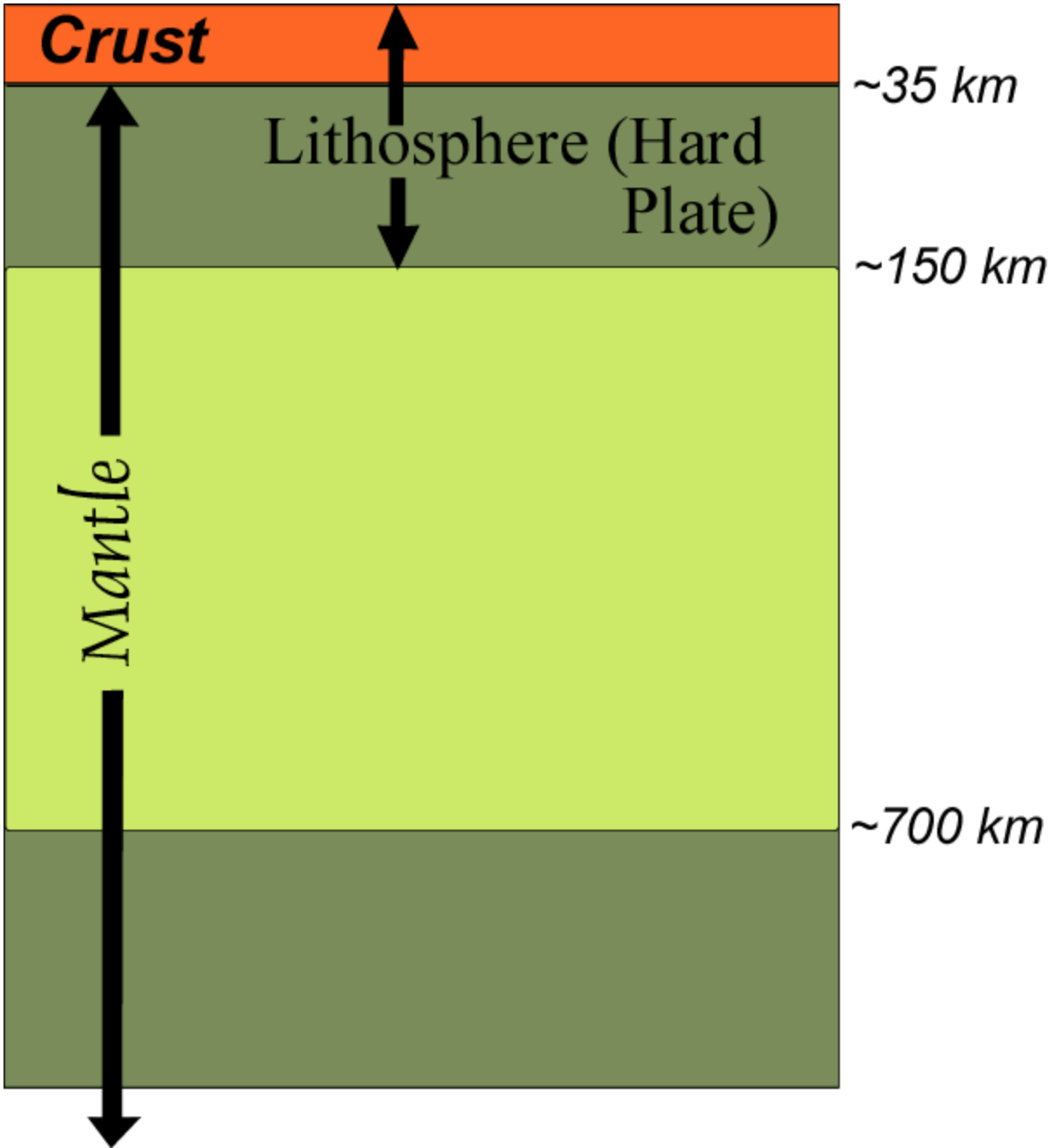
Oreo® Cookie


Hard Upper Cookie
Creamy Filling
Hard Lower Cookie


Crust
~35 km
~150 km
Mantle
~700 km

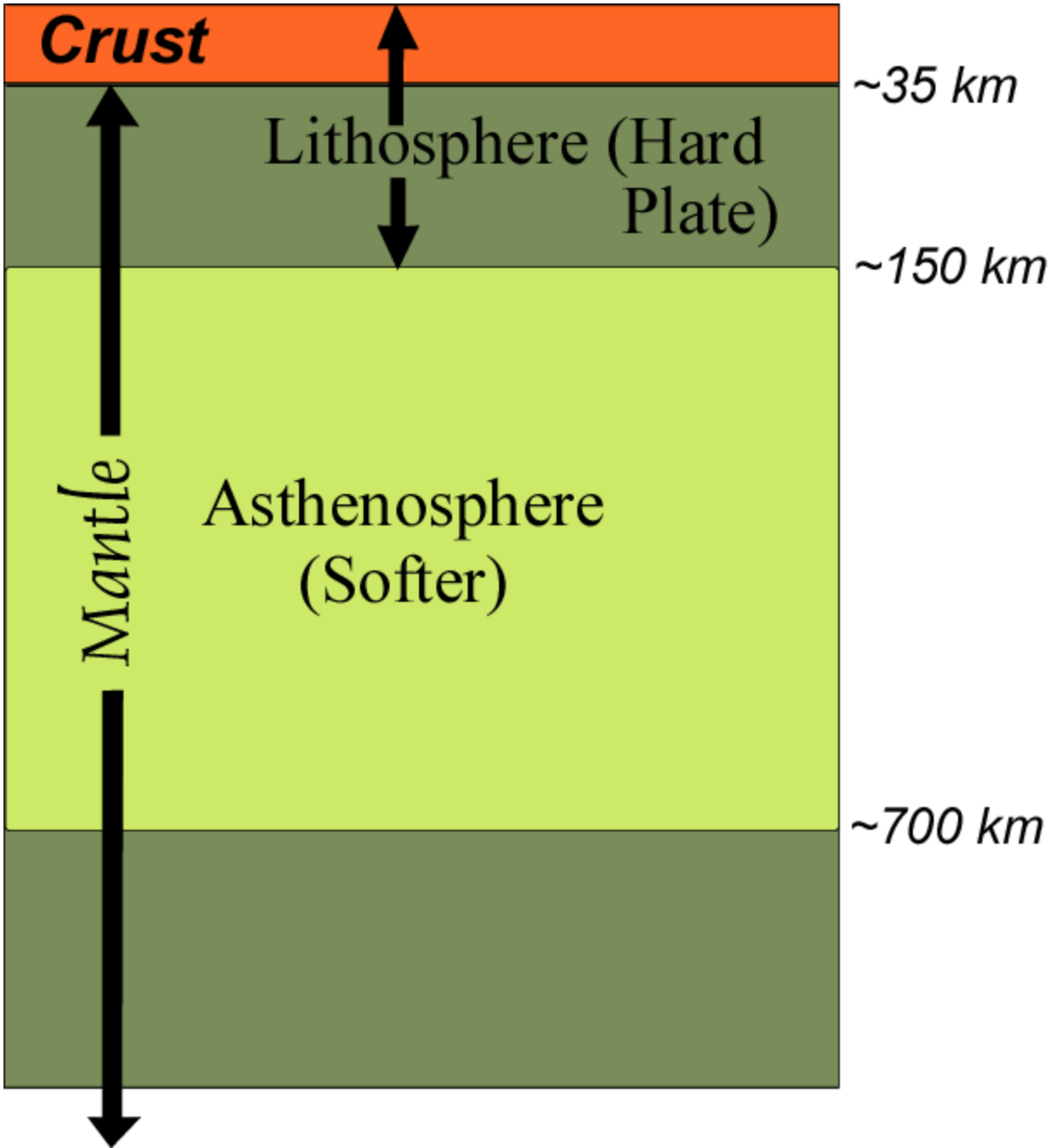
Oreo® Cookie


Hard Upper Cookie
Creamy Filling
Hard Lower Cookie


Crust
~35 km
Lithosphere (Hard Plate)
~150 km
Mantle
~700 km

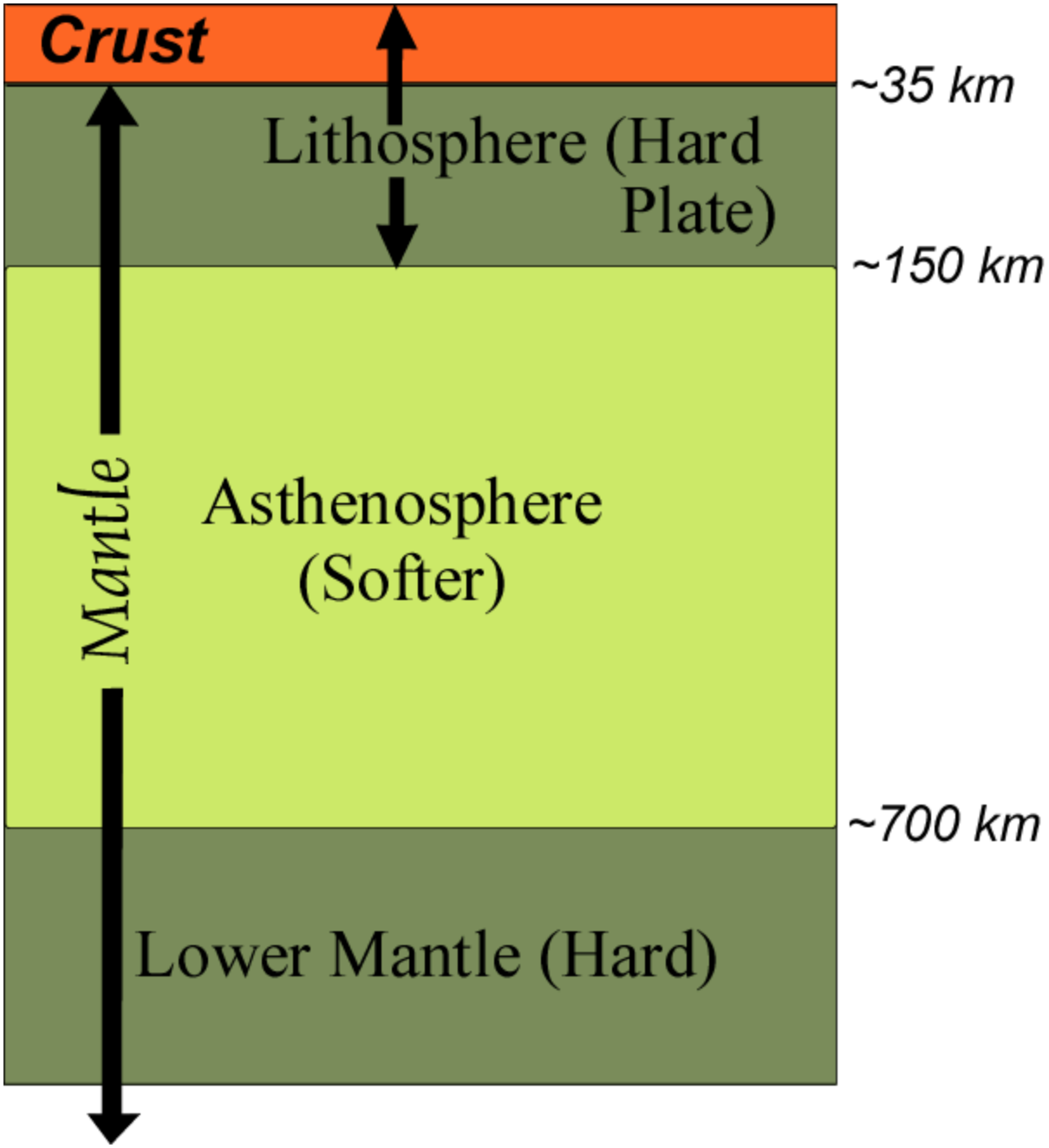
Oreo® Cookie


Hard Upper Cookie
Creamy Filling
Hard Lower Cookie


Crust
~35 km
Lithosphere (Hard Plate)
~150 km
Mantle
Asthenosphere (Softer)
~700 km

Oreo® Cookie


Hard Upper Cookie
Creamy Filling
Hard Lower Cookie


Crust
~35 km
Lithosphere (Hard Plate)
~150 km
Mantle
Asthenosphere (Softer)
~700 km
Lower Mantle (Hard)


Robert J. Lillie

Oreo® Psycho-Personality Test

www.superkids.com/aweb/pages/humor/050199.sht

- **Psychologists have discovered that the manner in which people eat Oreo® cookies provides great insight into their personalities. Choose which method best describes your favorite method of eating Oreos:**
- **1. The whole thing at once.**
  2. One bite at a time.
  3. Slow and methodical nibbles examining the results of each bite afterwards.
  4. In little feverous nibbles.
  5. Dunked in some liquid (milk, coffee …..)
  6. Twisted apart, the inside, then the cookie.
  7. Twisted apart, the inside, and toss the cookie.
  8. Just the cookie, not the inside.
  9. I just like to lick them, not eat them.
  10. I don't have a favorite way because I don't like Oreos.

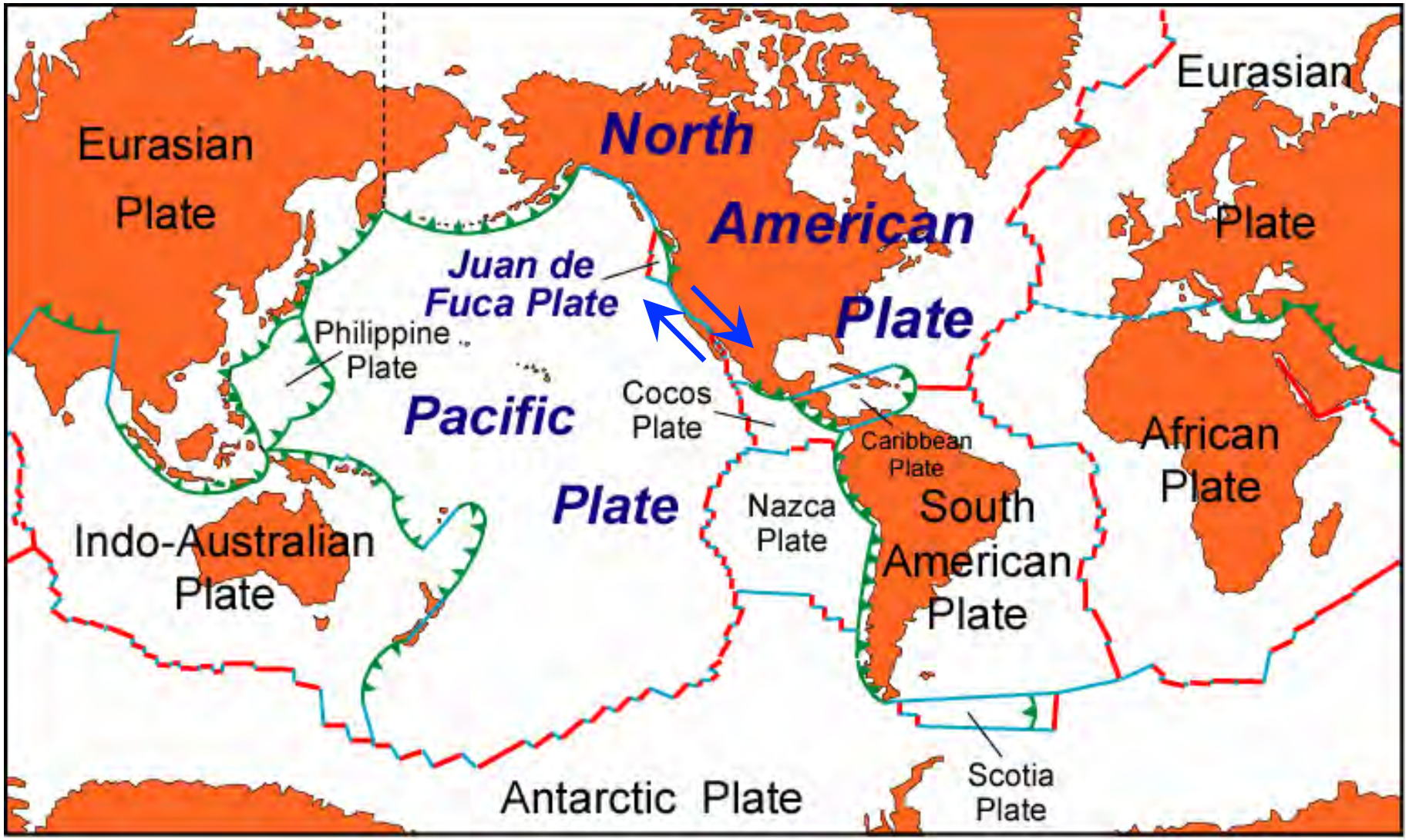
6. Twisted apart, the inside, then the cookie.

- You have a highly curious nature.
- You take pleasure in breaking things apart to find out how they work, though you're not always able to put them back together, so you destroy all the evidence of your activities.
- You deny your involvement when things go wrong.
- You are a compulsive liar and exhibit deviant, if not criminal, behavior.

Sliding Plate over Asthenosphere

Transform Plate Boundary

Transform Plate Boundary



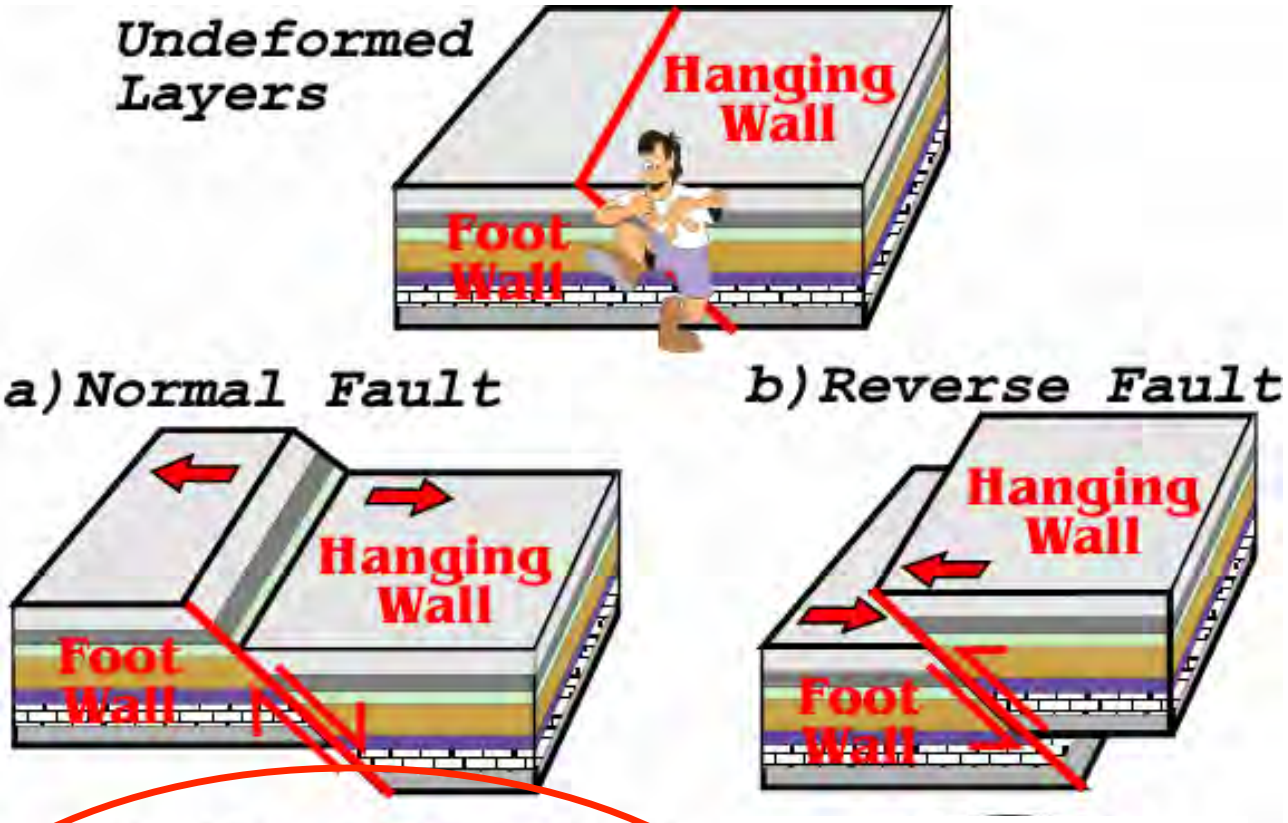
San Andreas Fault

Transform Plate Boundary

The Pacific Plate slides past the North American Plate along the <u>San Andreas Fault</u> in California.

Marshak, EARTH (Norton, 2005)

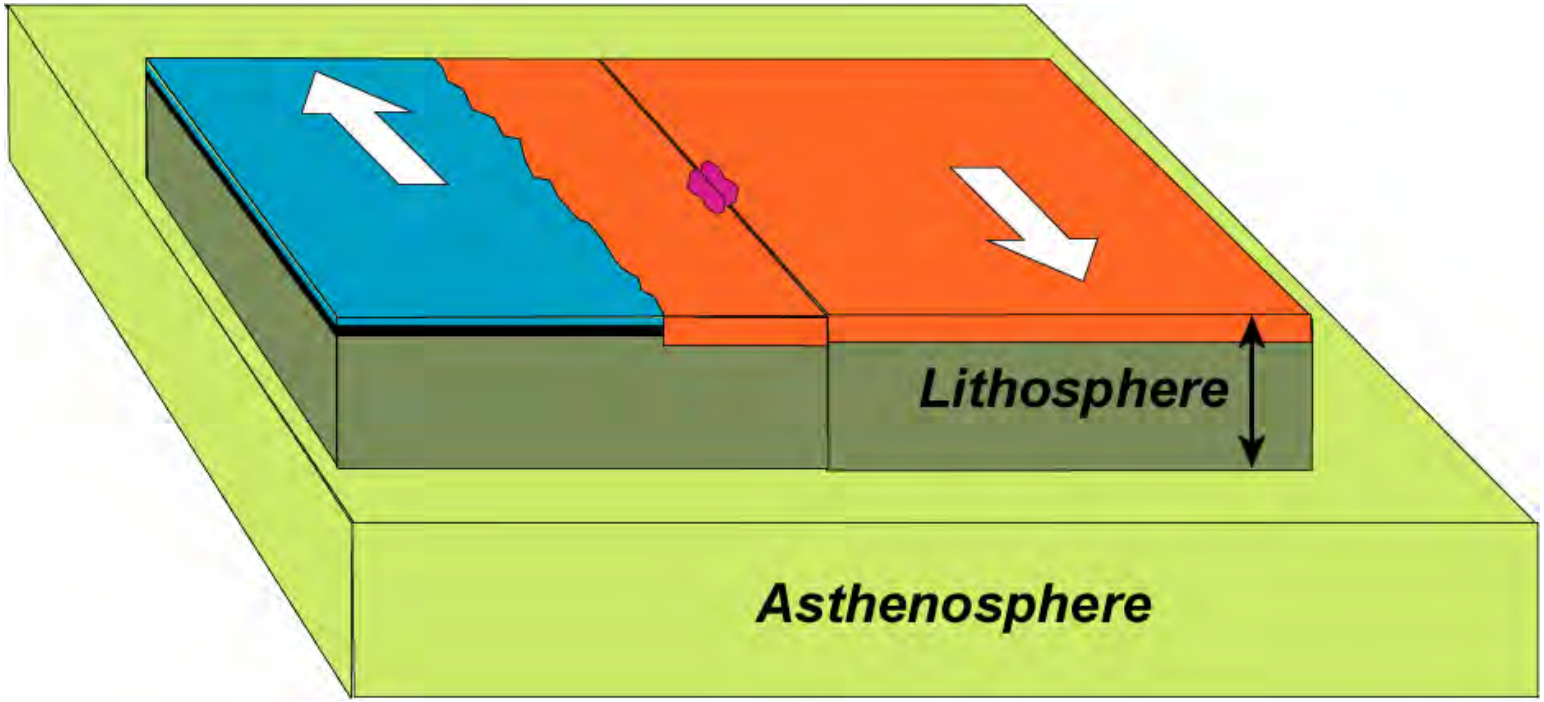
Activities: Binder p. 5 – "Foam Faults"



Activities: Binder p. 5 – "Foam Faults"

TRANSFORM PLATE BOUNDARY

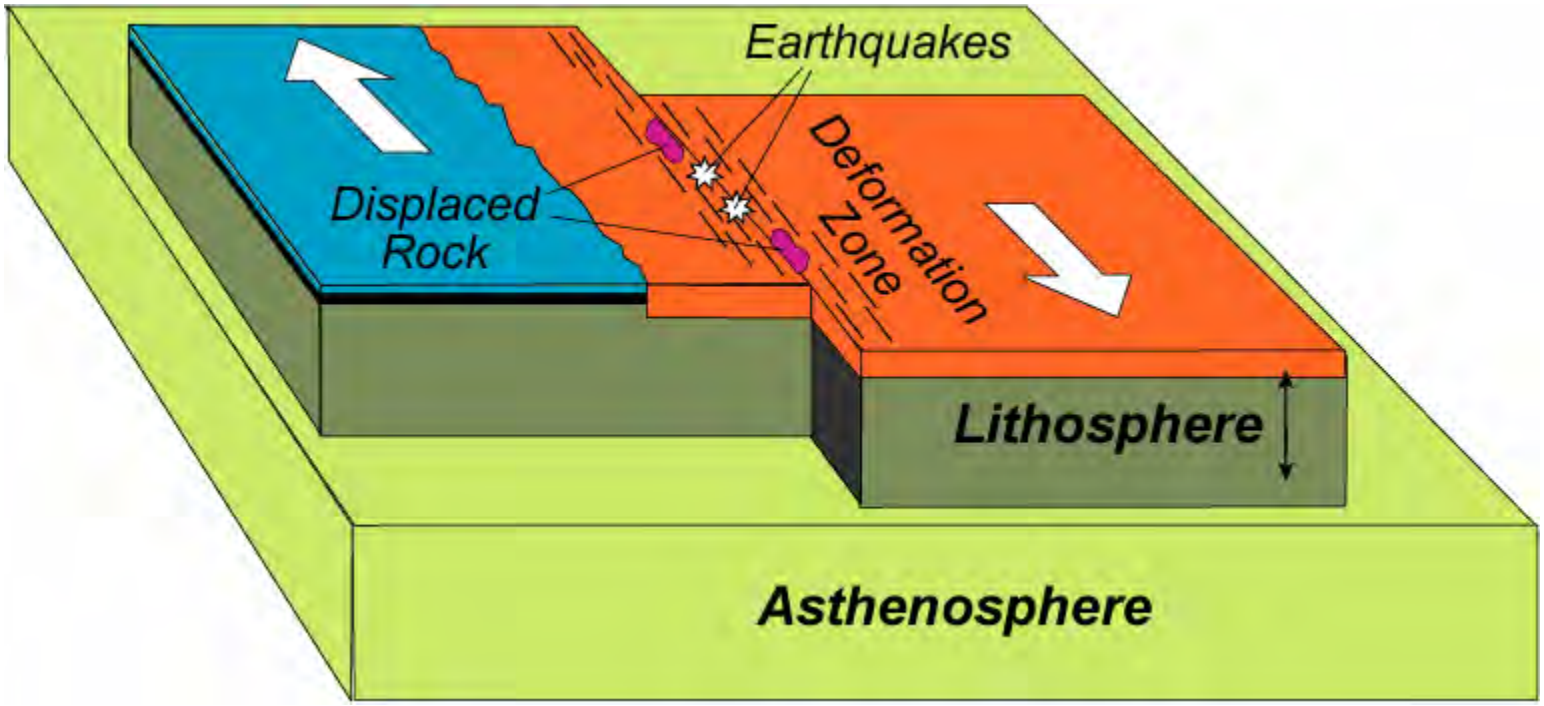
(Western California)



Activities: Binder p. 5 – "Foam Faults"

TRANSFORM PLATE BOUNDARY

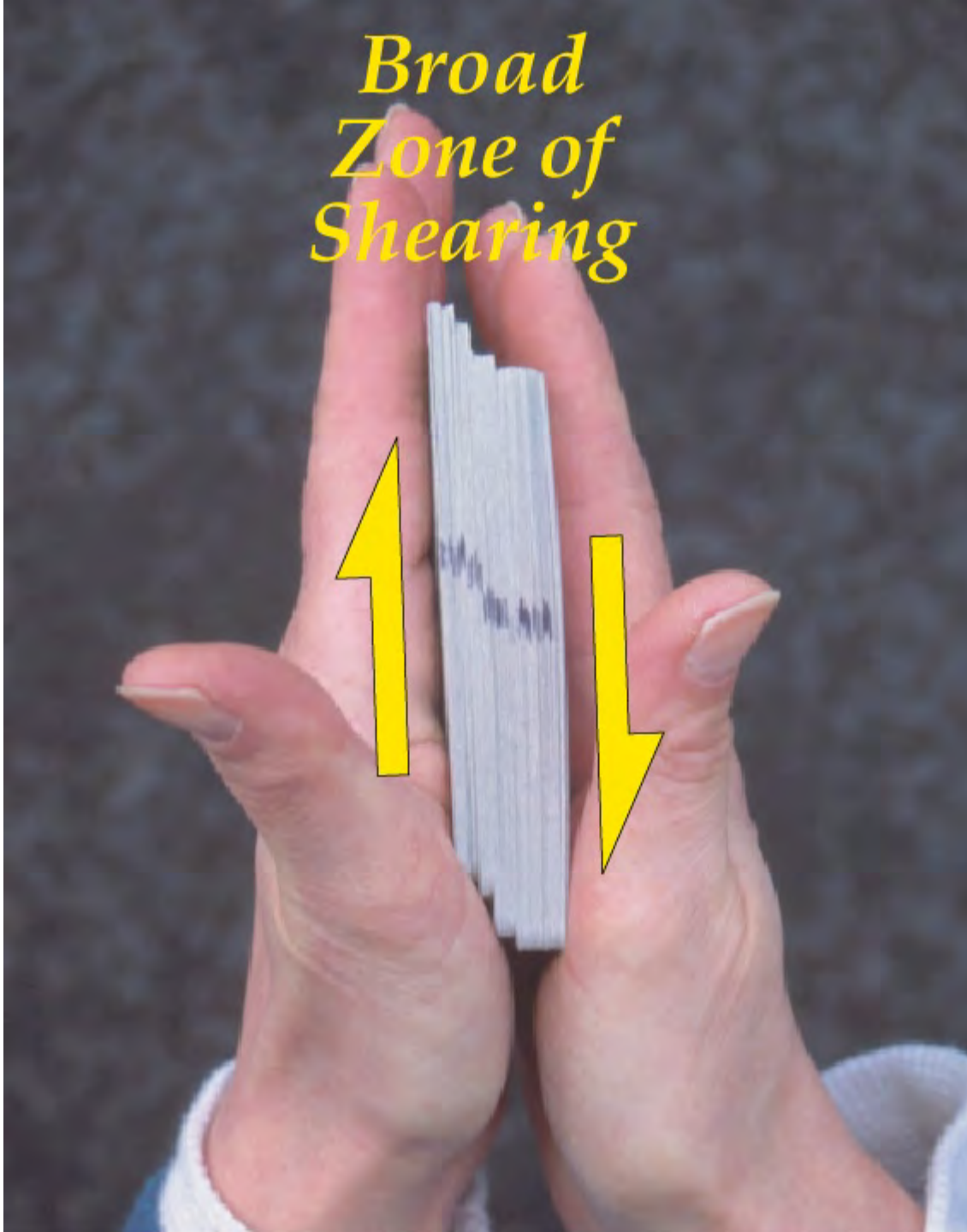
(Western California)



Shearing Forces Produce Strike-Slip Faults

Creating the SAN ANDREAS FAULT with a Deck of Cards

The TRANSFORM PLATE BOUNDARY is a broad zone of shearing between the two plates.



Creating the SAN ANDREAS FAULT with a Deck of Cards

One card face eventually takes over, simulating the predominance of movement along the San Andreas Fault.

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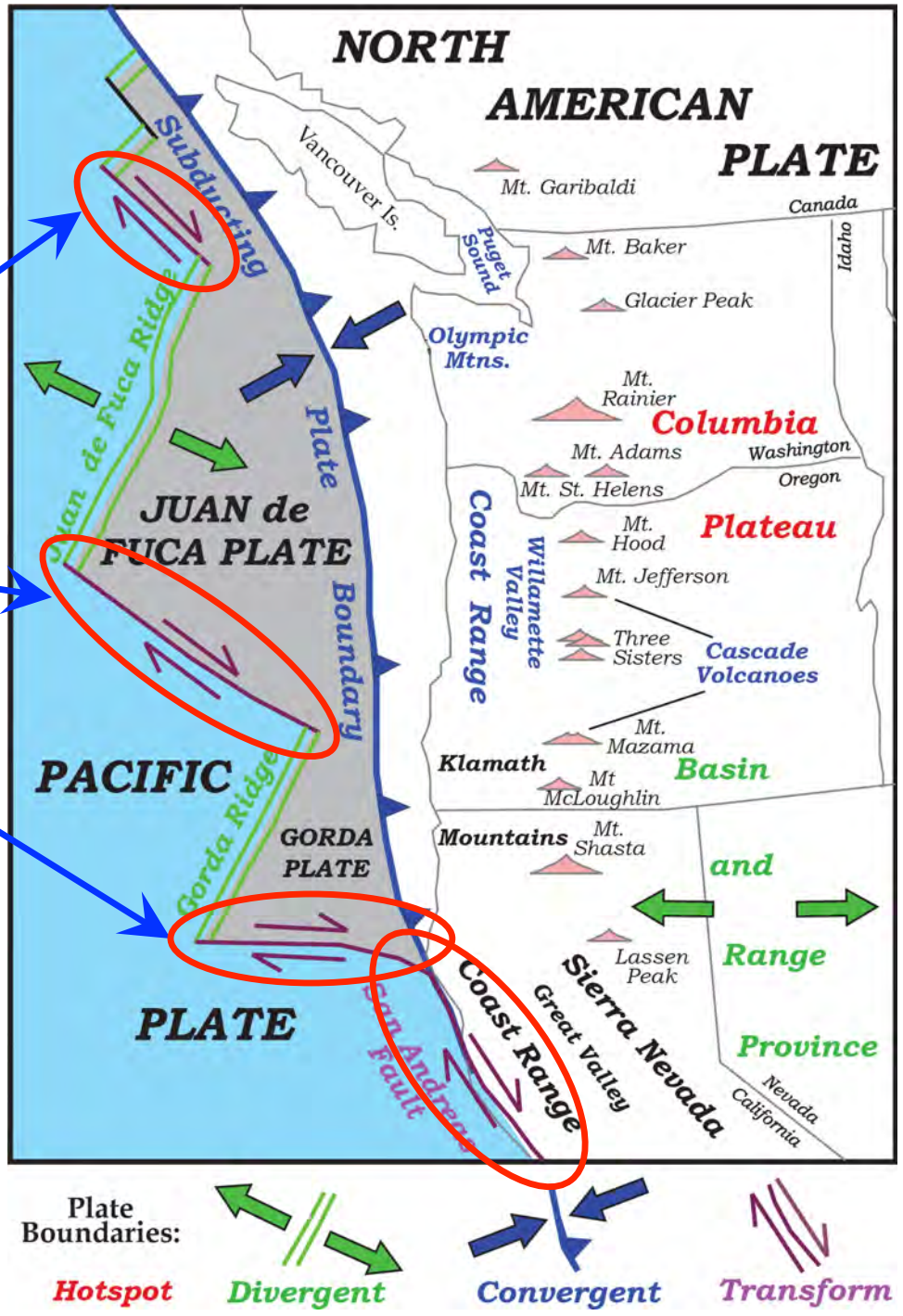
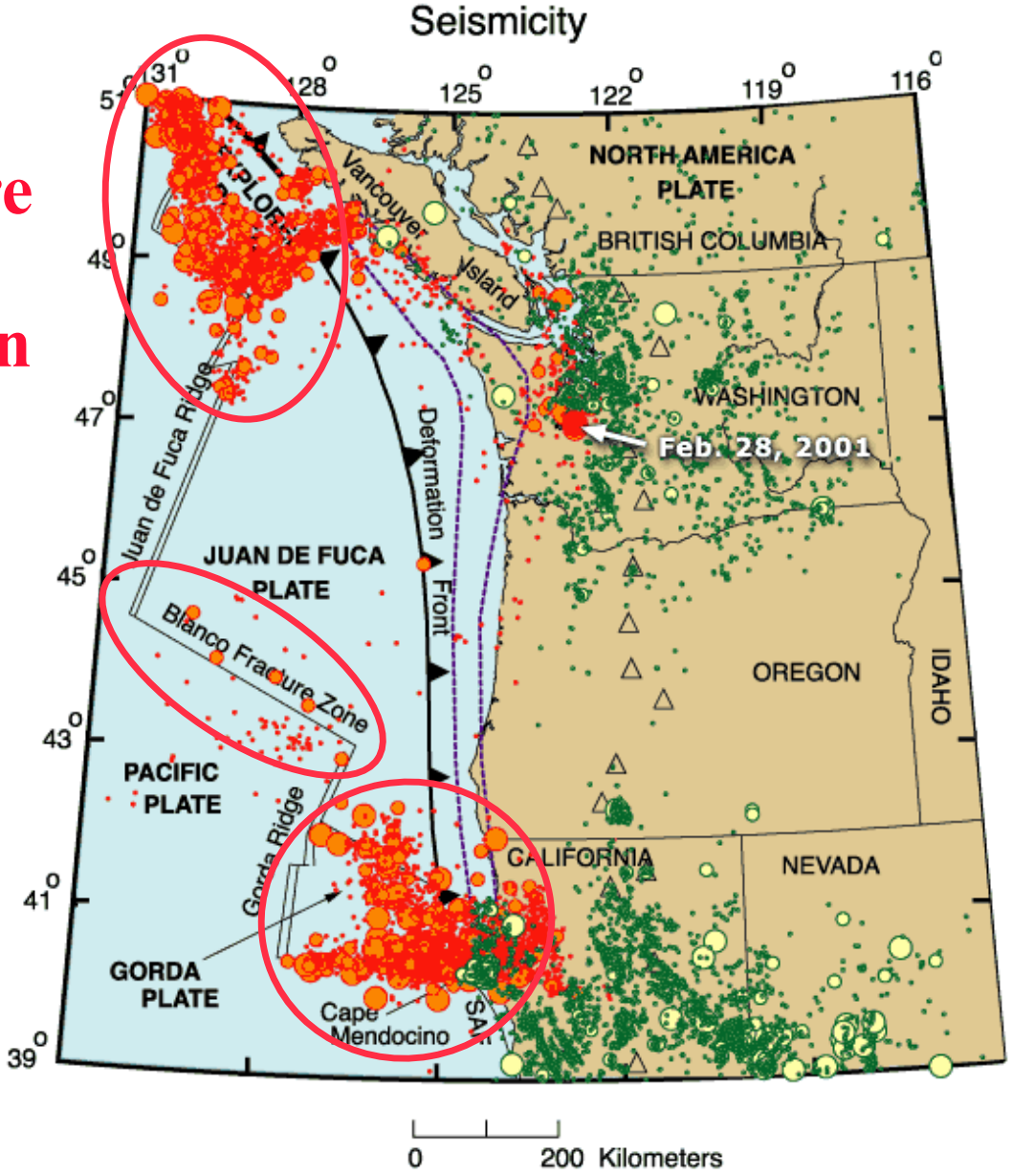
Transform Plate Boundaries



Earthquakes in the Pacific Northwest

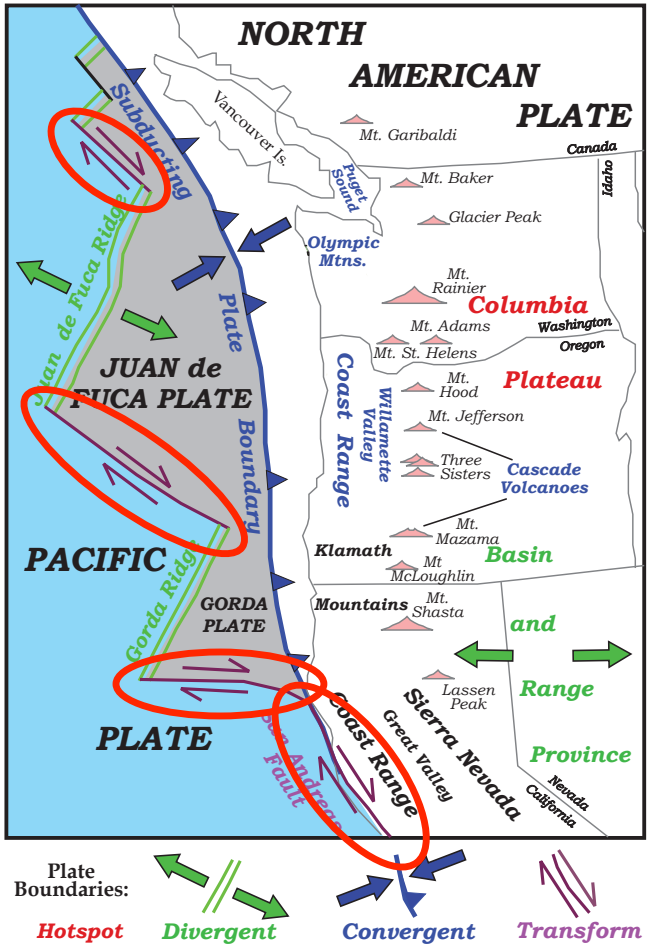
Offshore earthquakes are commonly on transform plate boundaries between the Pacific and Juan de Fuca Plates.



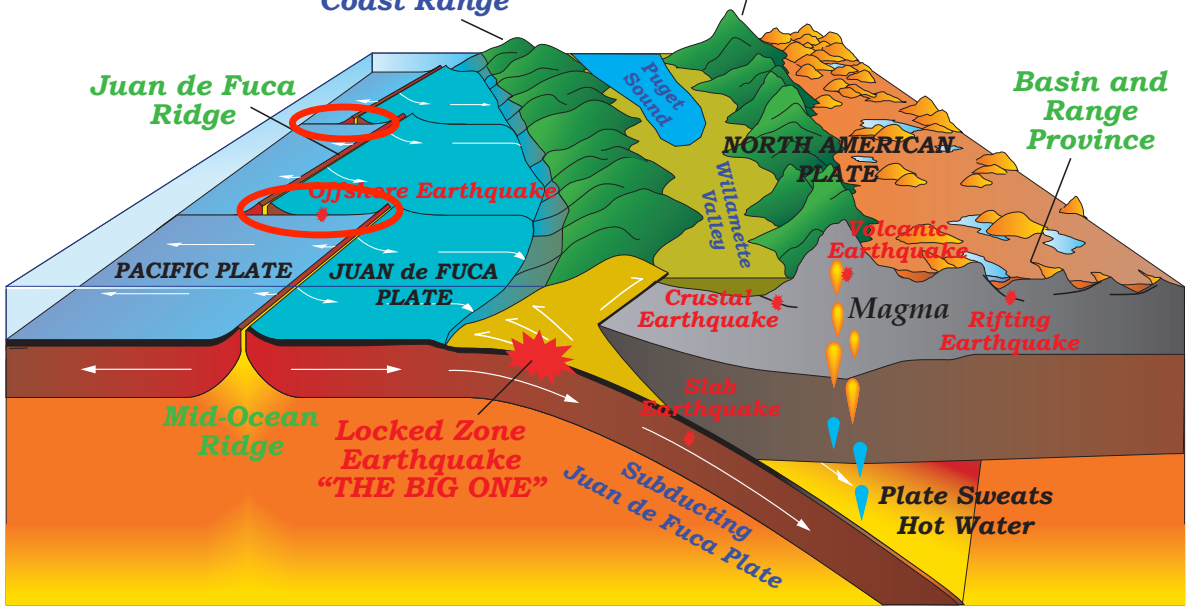
modified from Weaver and Shedlock, 1996

Transform Plate Boundaries

Plate Tectonics of the Pacific Northwest



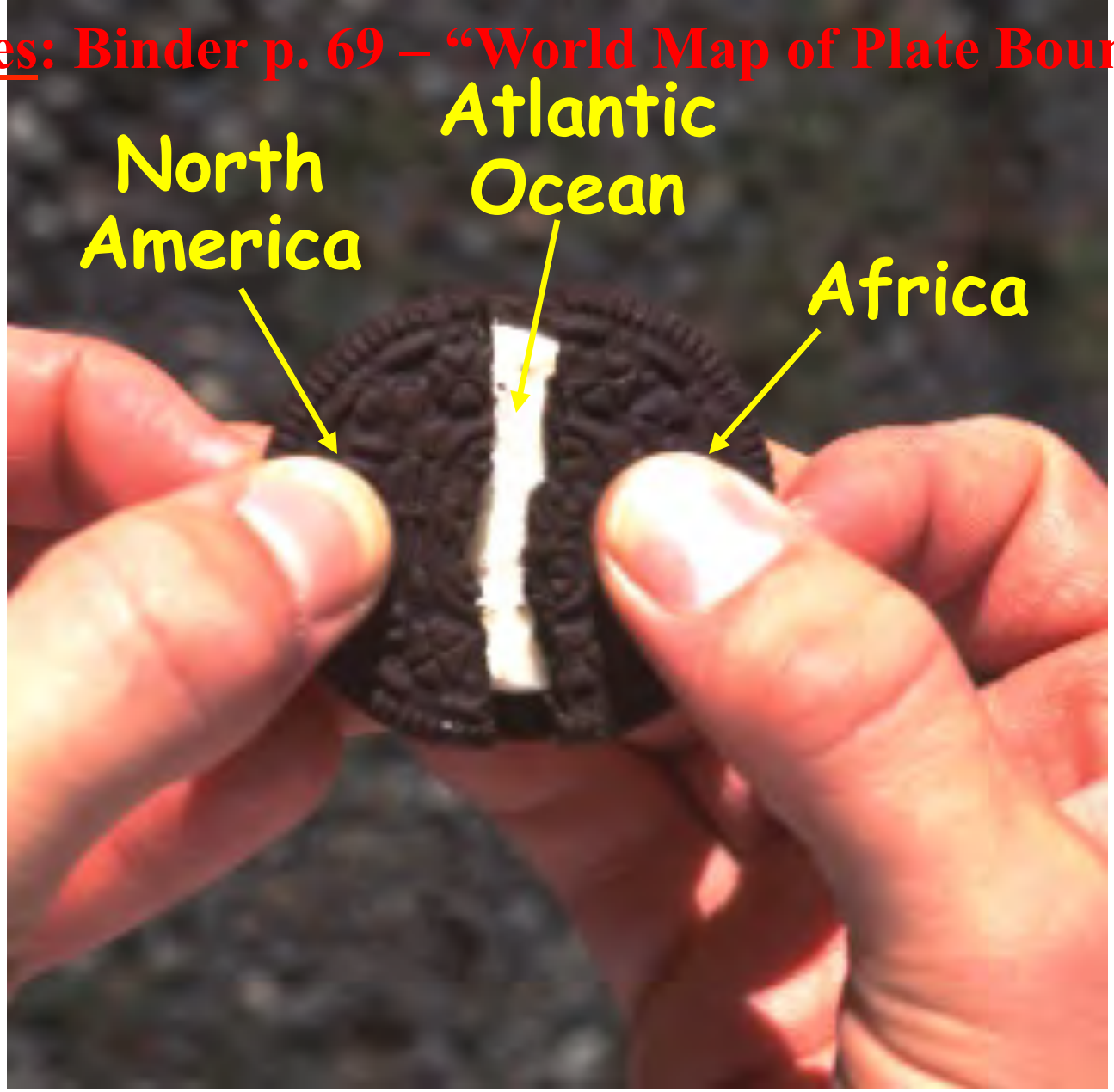
Cascadia Subduction Zone



Cascadia EarthScope Earthquake and Tsunami Education Program

http://ceetep.oregonstate.edu

Activities: Binder p. 69 – "World Map of Plate Boundaries"



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Divergent Plate Boundary


Activities: Binder p. 69 – "World Map of Plate Boundaries"
Iceland
North America
Mid-Atlantic Ridge
(Divergent Plate Boundary)
Africa
National Geographic

Iceland


Iceland

Activities: Binder p. 69 – "World Map of Plate Boundaries"

Three Stages of Plate Divergence

Earth from Space

National Aeronautics and Space Administration

Activities: Binder p. 69 – "World Map of Plate Boundaries"

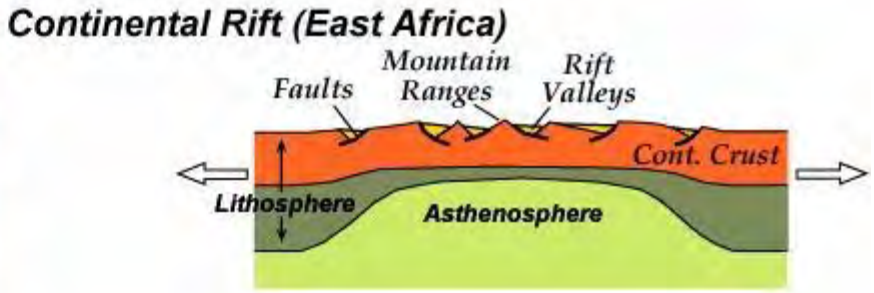
Three Stages Of Divergent Plate Boundary Development

Marshak, EARTH (Norton, 2005)

Activities: Binder p. 69 – "World Map of Plate Boundaries"

Three Stages Of Divergent Plate Boundary Development

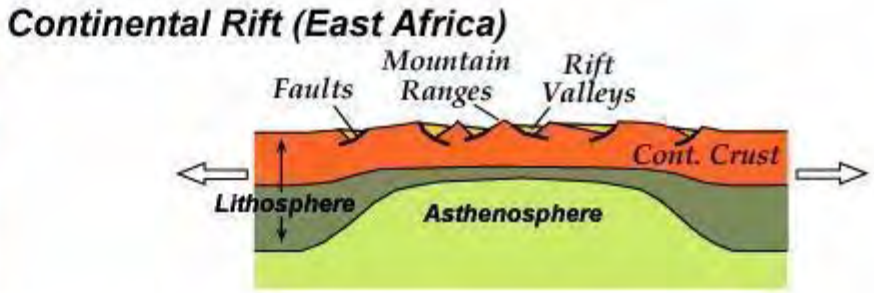
Marshak, EARTH (Norton, 2005)

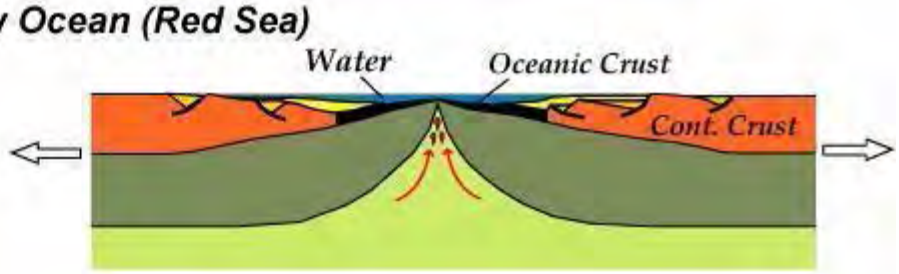


Activities: Binder p. 69 – "World Map of Plate Boundaries"

Three Stages Of Divergent Plate Boundary Development

Marshak, EARTH (Norton, 2005)



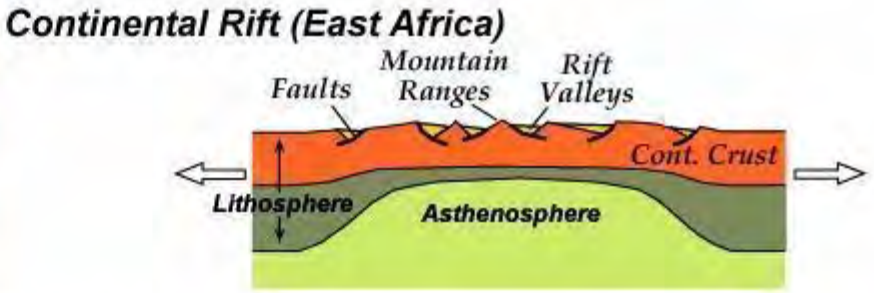


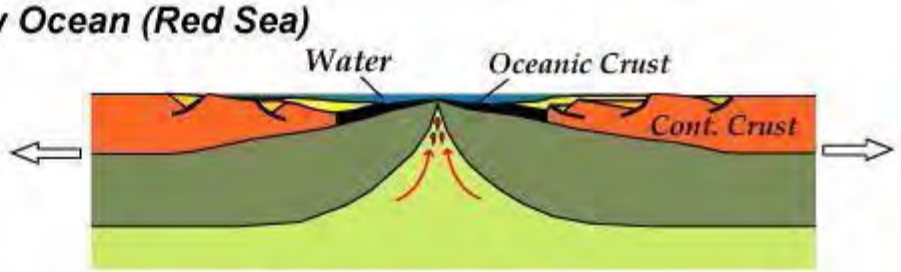
Parks and Plates

Activities: Binder p. 69 – "World Map of Plate Boundaries"

Three Stages Of Divergent Plate Boundary Development

Marshak, EARTH (Norton, 2005)

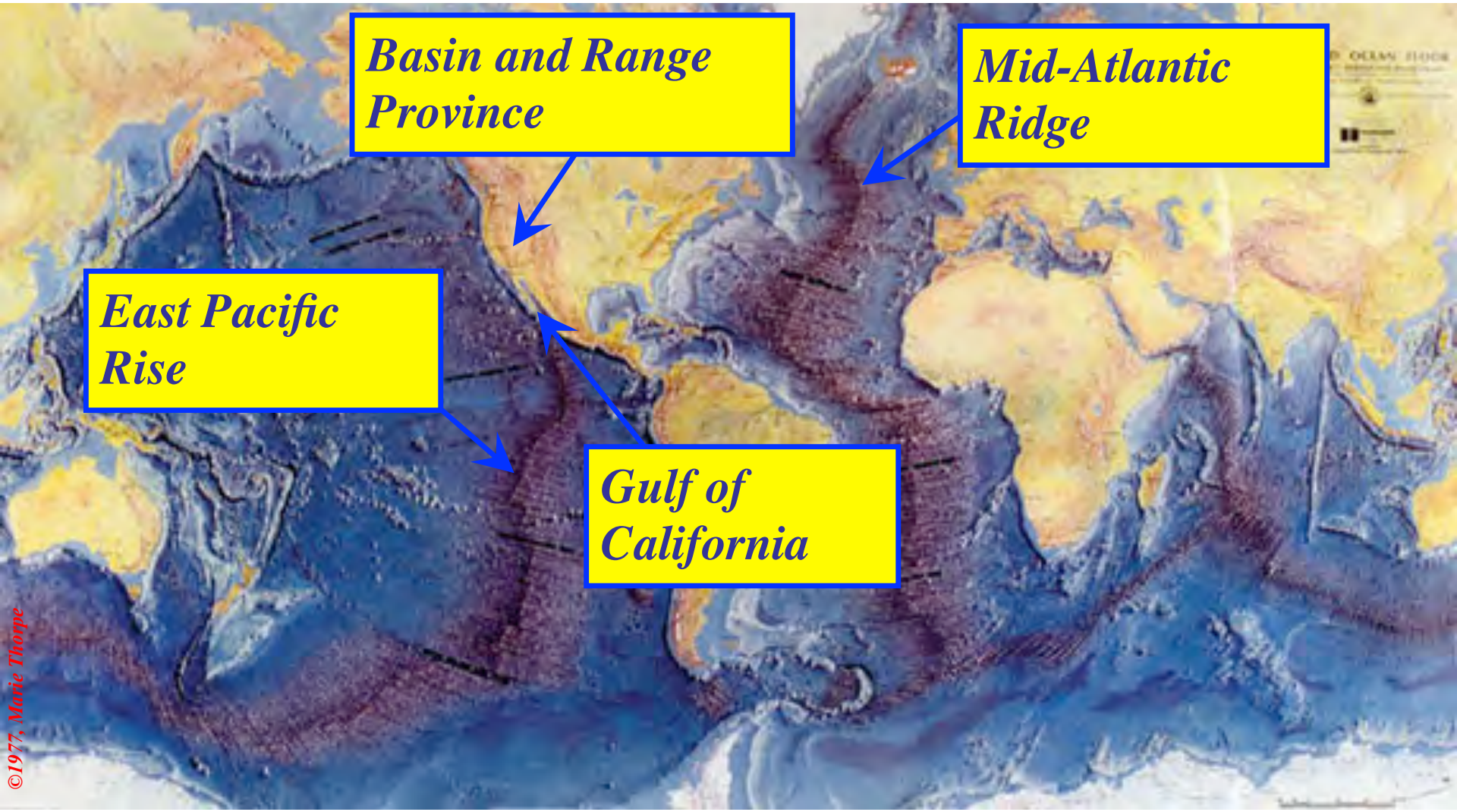




Parks and Plates

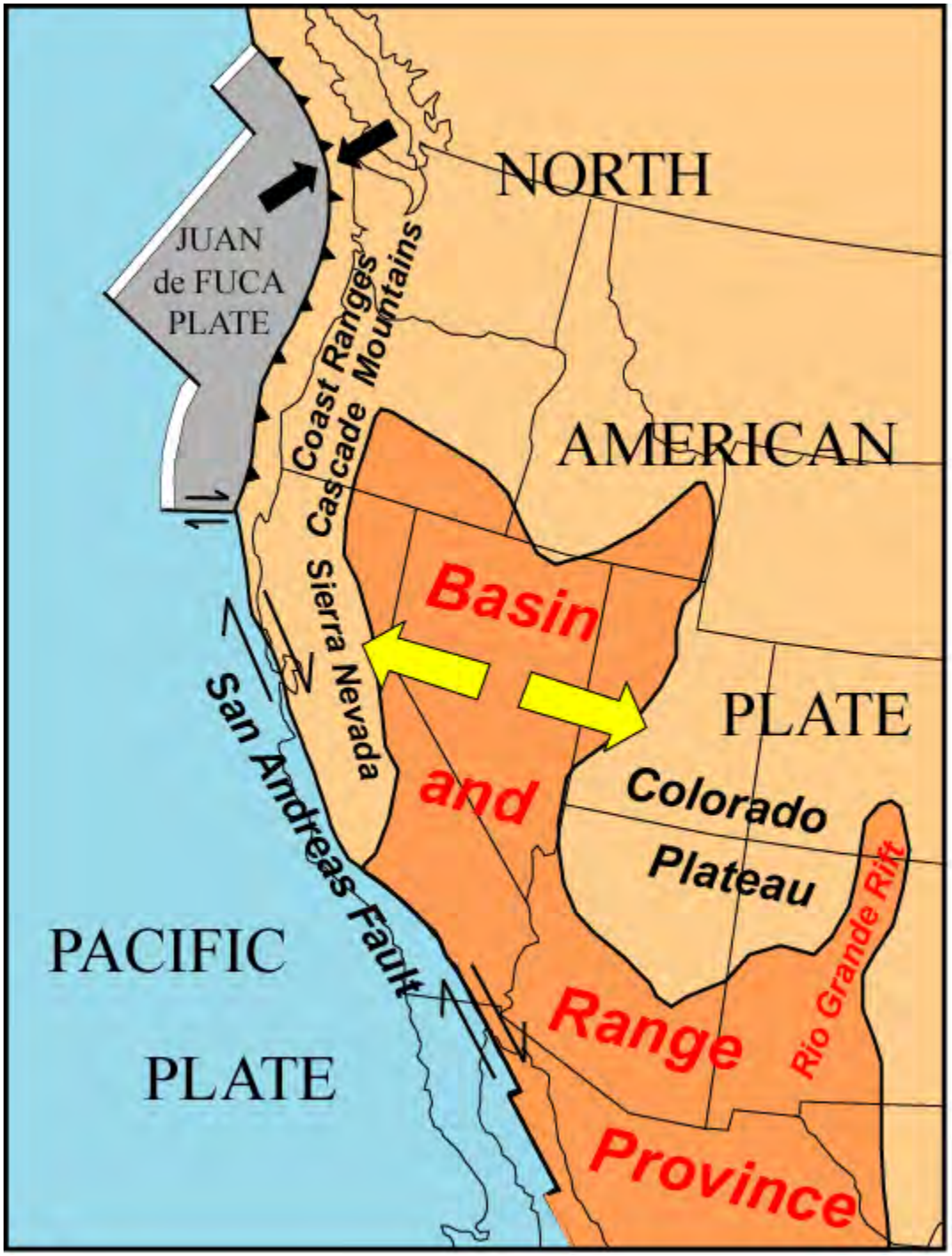
Activities: Binder p. 69 – "World Map of Plate Boundaries"

A Continental Rift can be viewed as the On-land Continuation of a Mid-Ocean Ridge



Divergent Plate Boundary

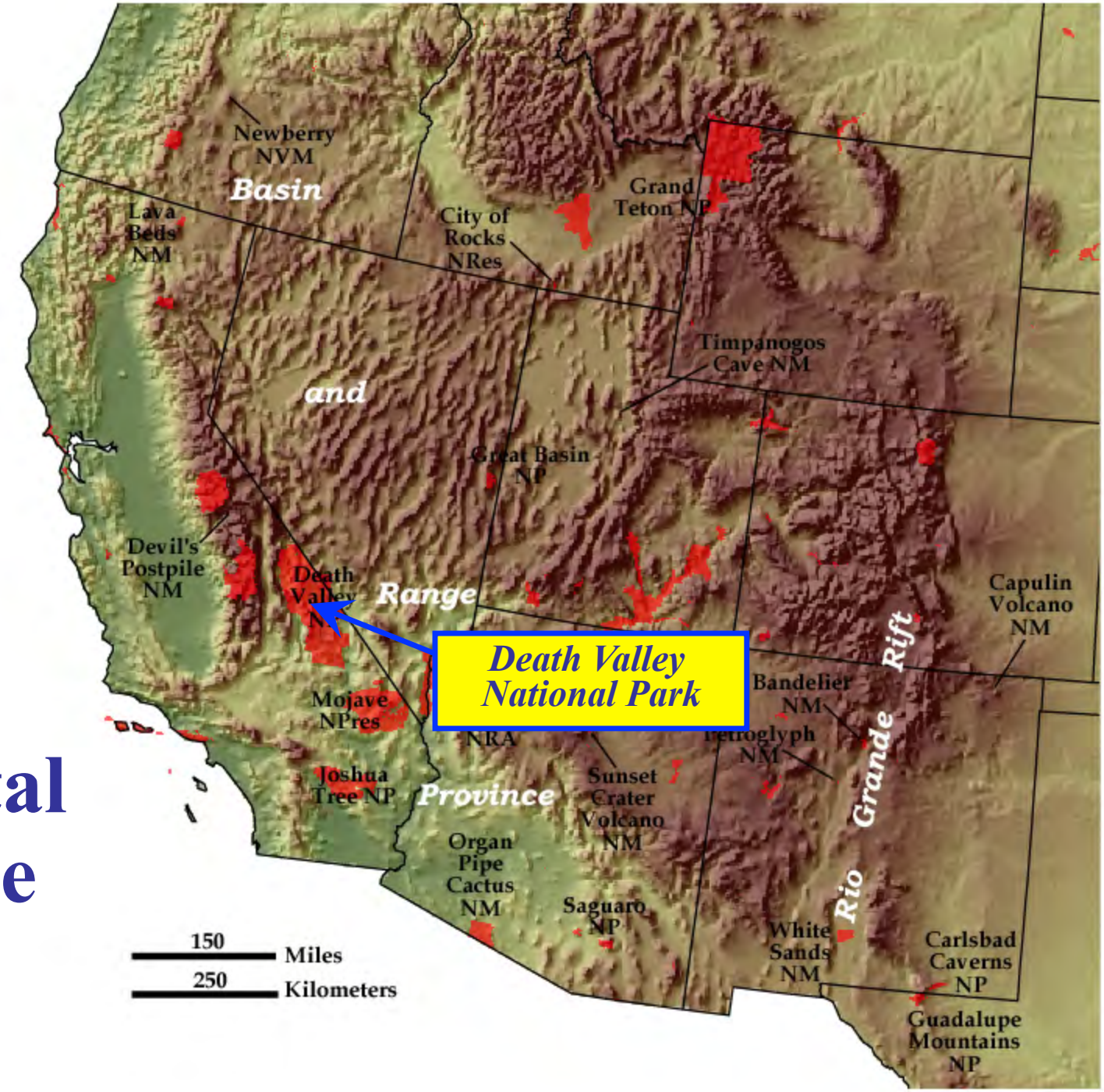
The <u>Basin and Range Province</u> is a Continental Rift Zone, the early stages of plate divergence



Plates Pulling Apart--Continental Rift Zone

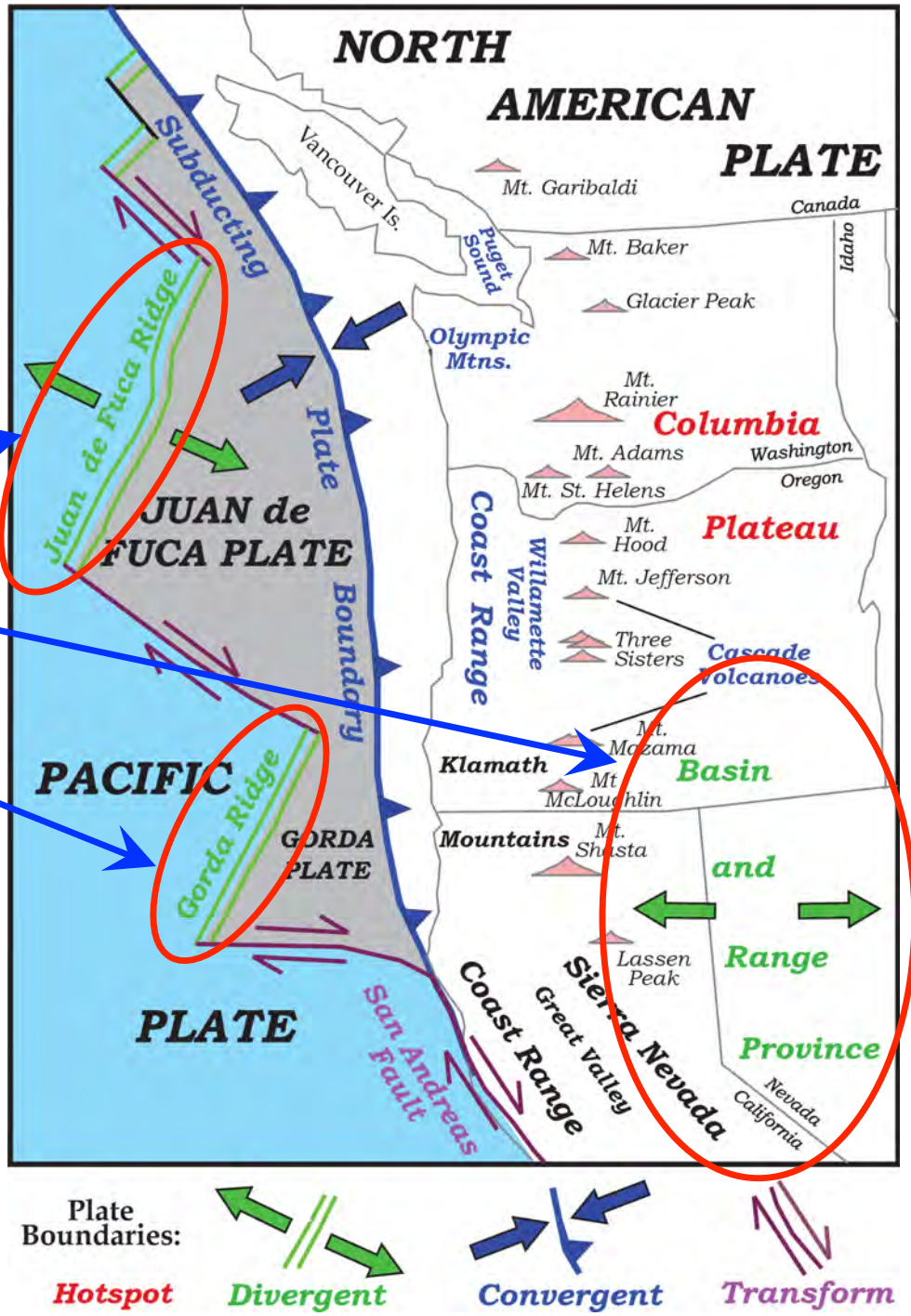
National Park Lands

Active Continental Rift Zone

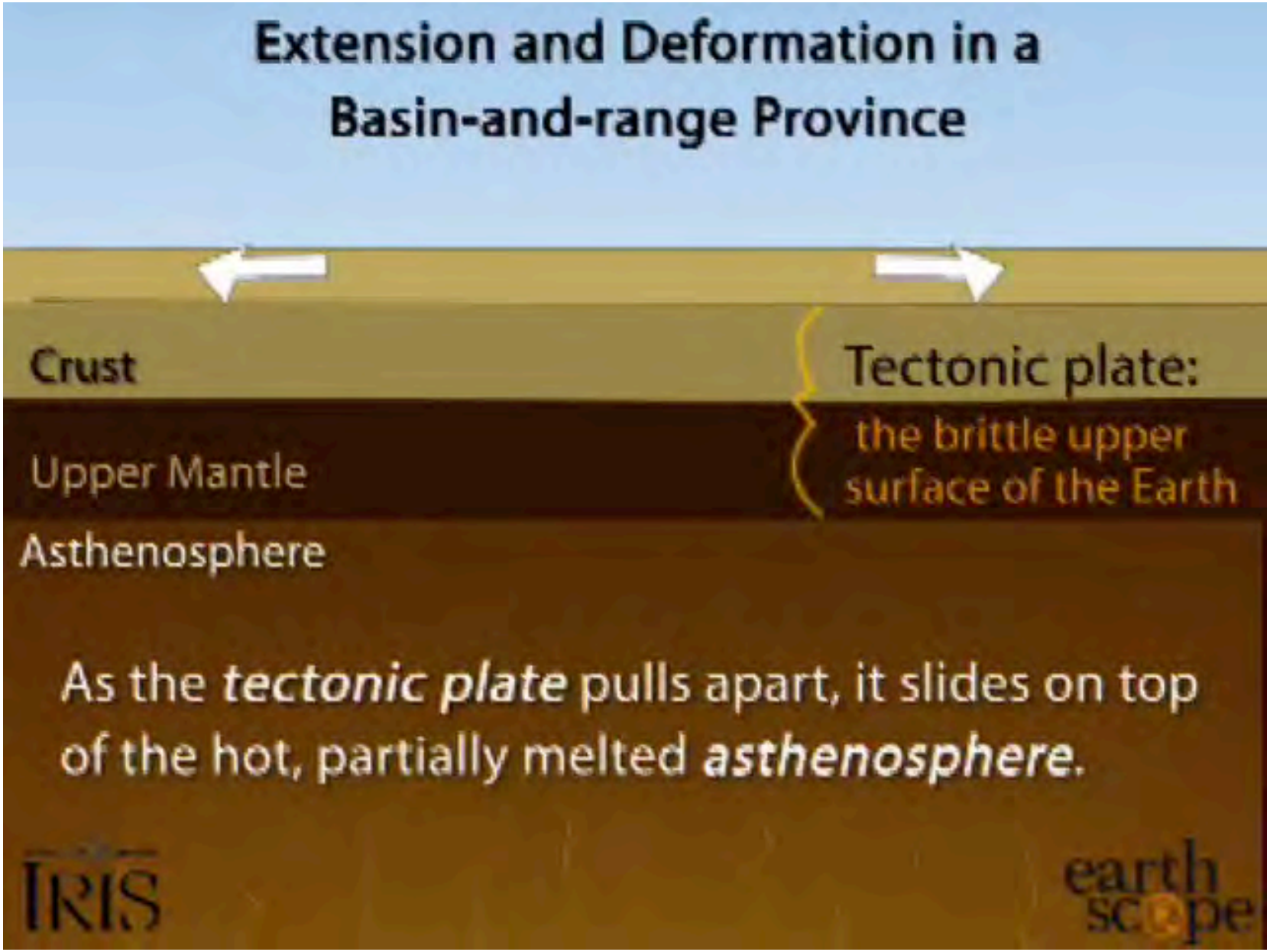


Death Valley National Park, California

Divergent Plate Boundaries

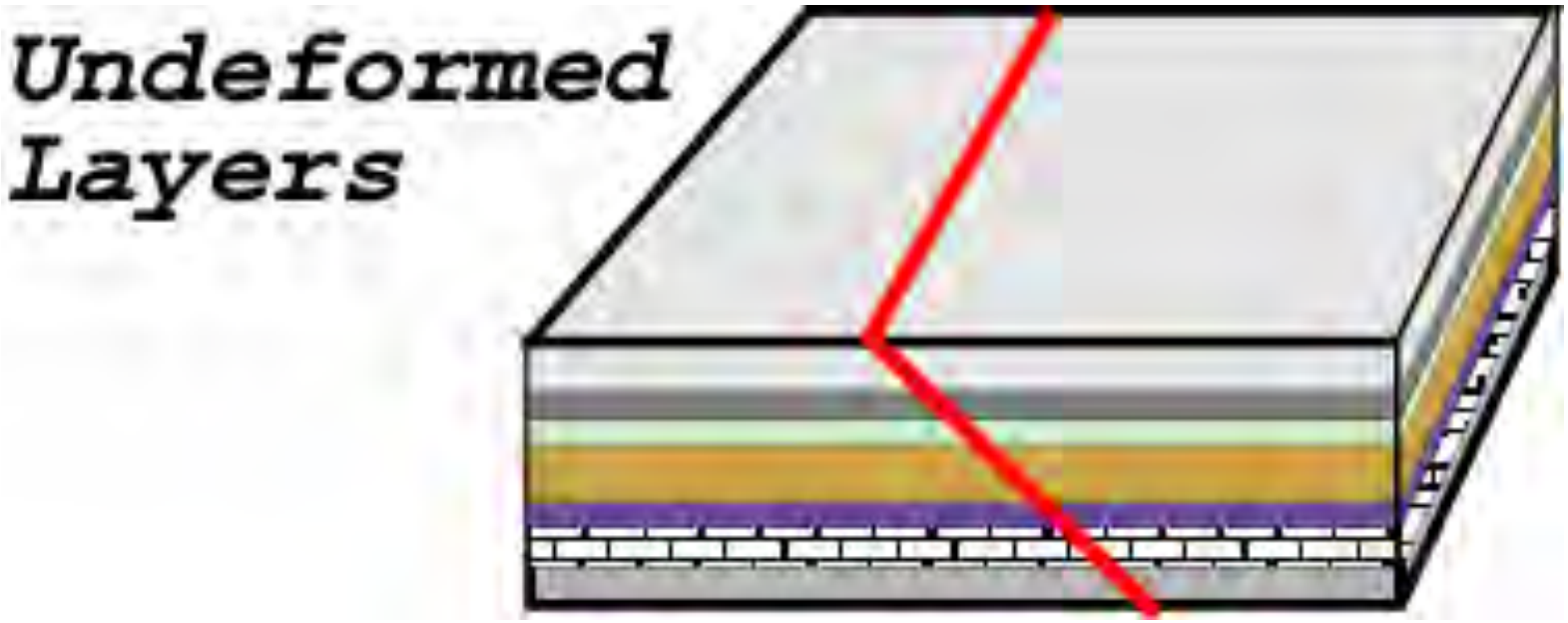


Activities: Binder p. 5 – "Foam Faults"



www.iris.edu (Animation by Jenda Johnson - Time 0:52)

Activities: Binder p. 5 – "Foam Faults"



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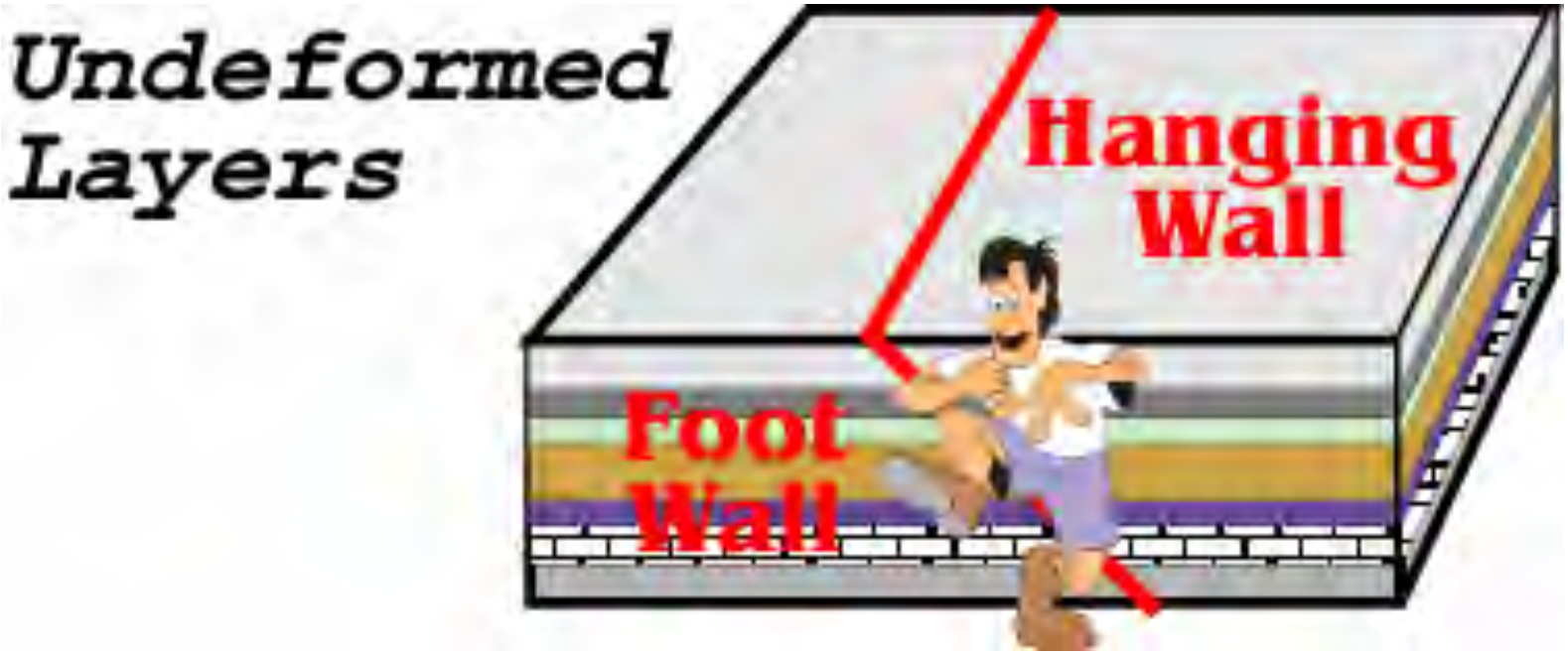

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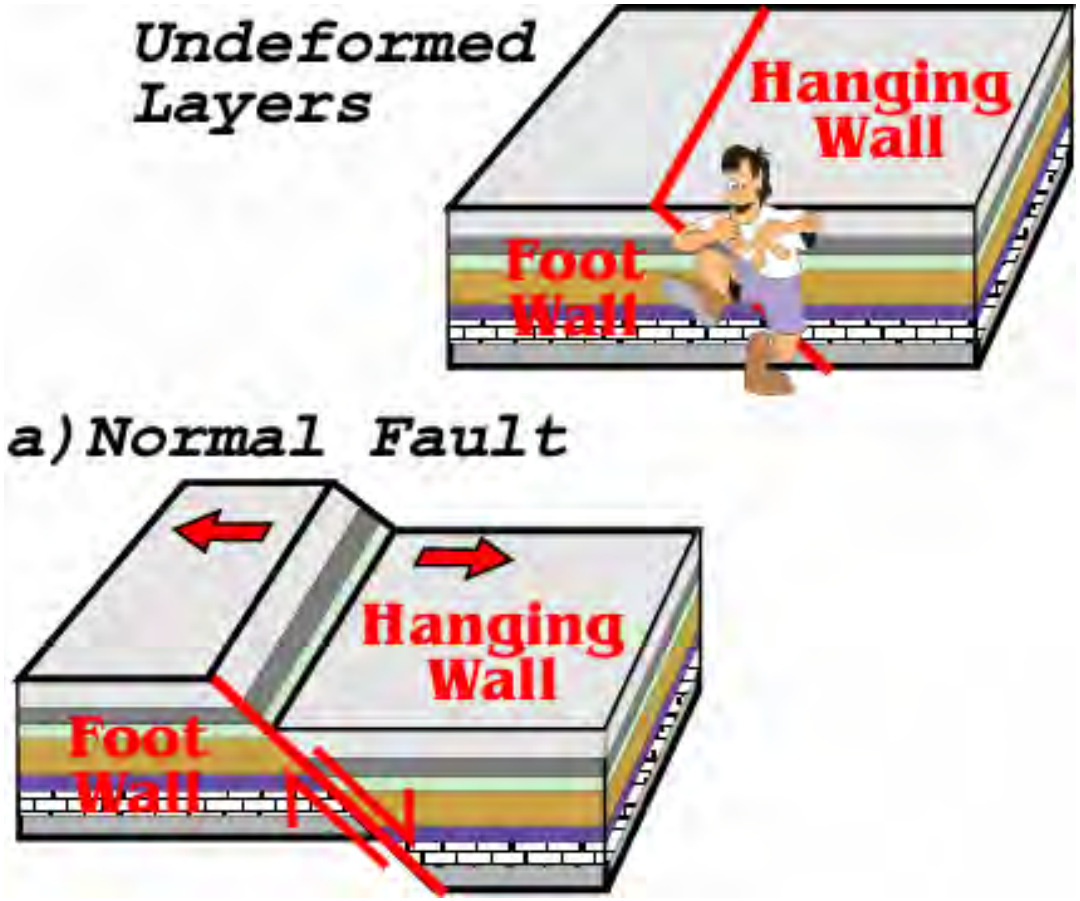
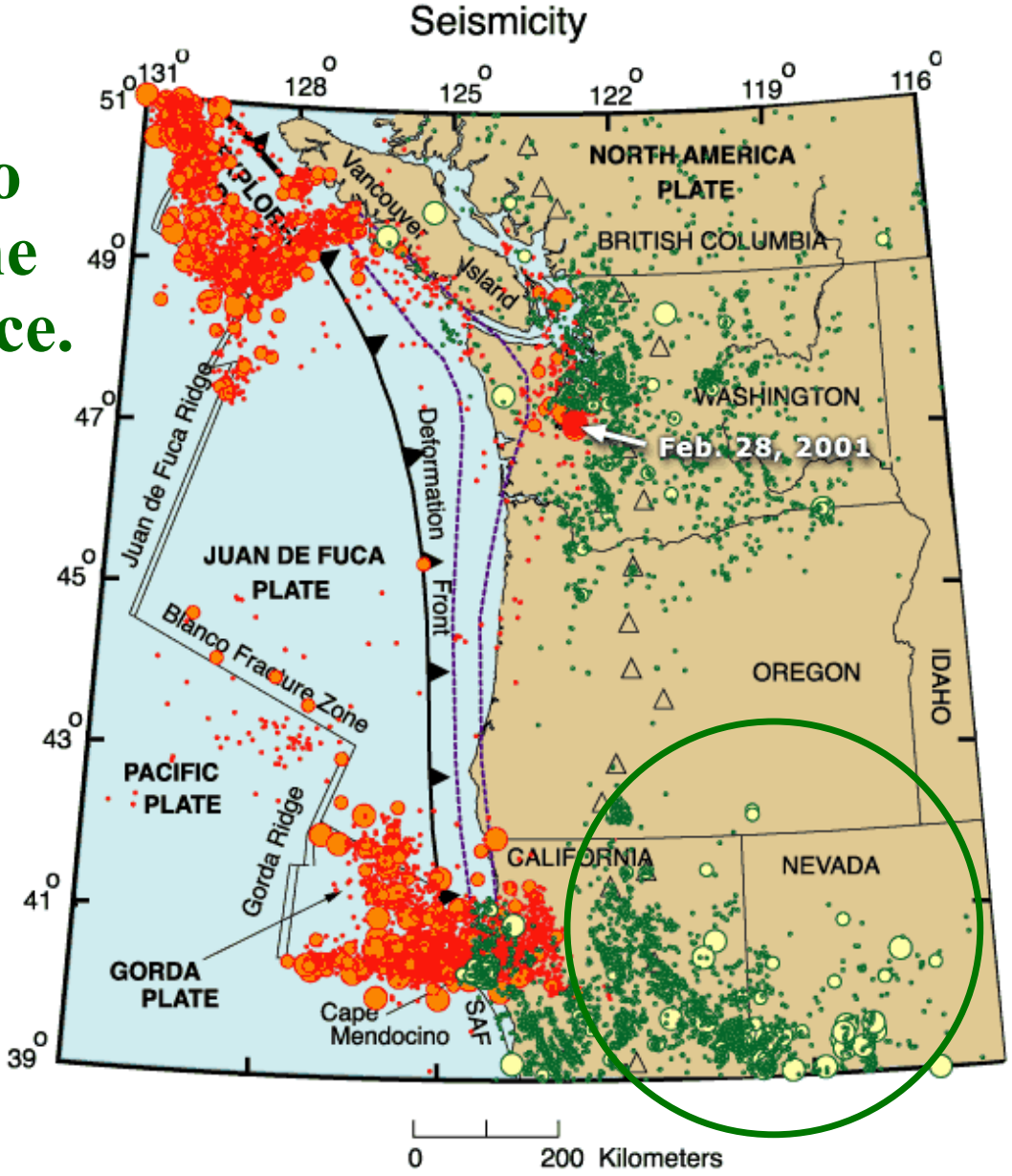


Earthquakes in the Pacific Northwest

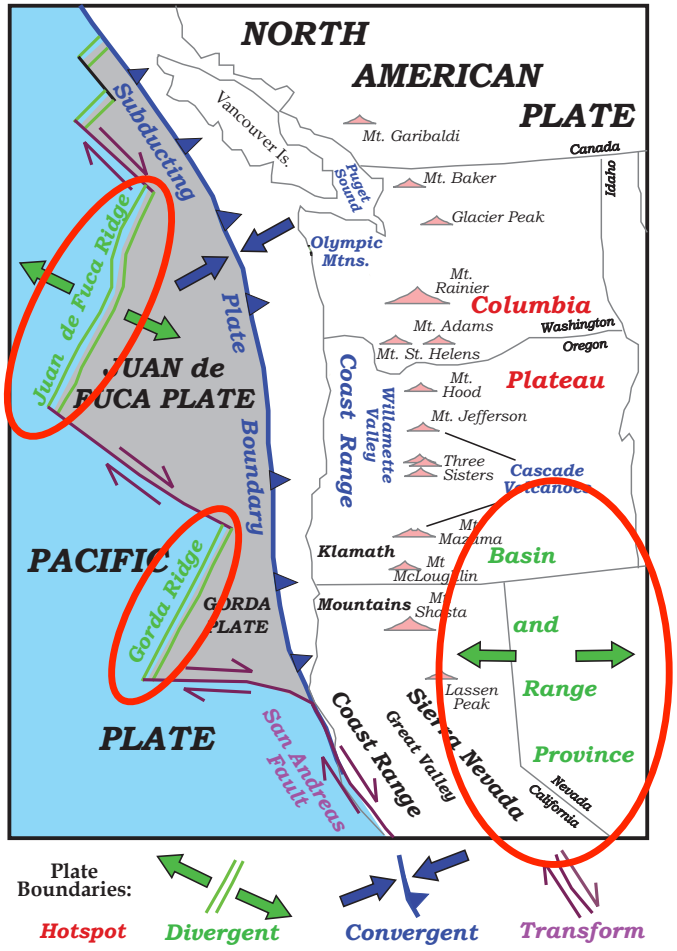
Some earthquakes due to Continental Rifting in the Basin and Range Province.

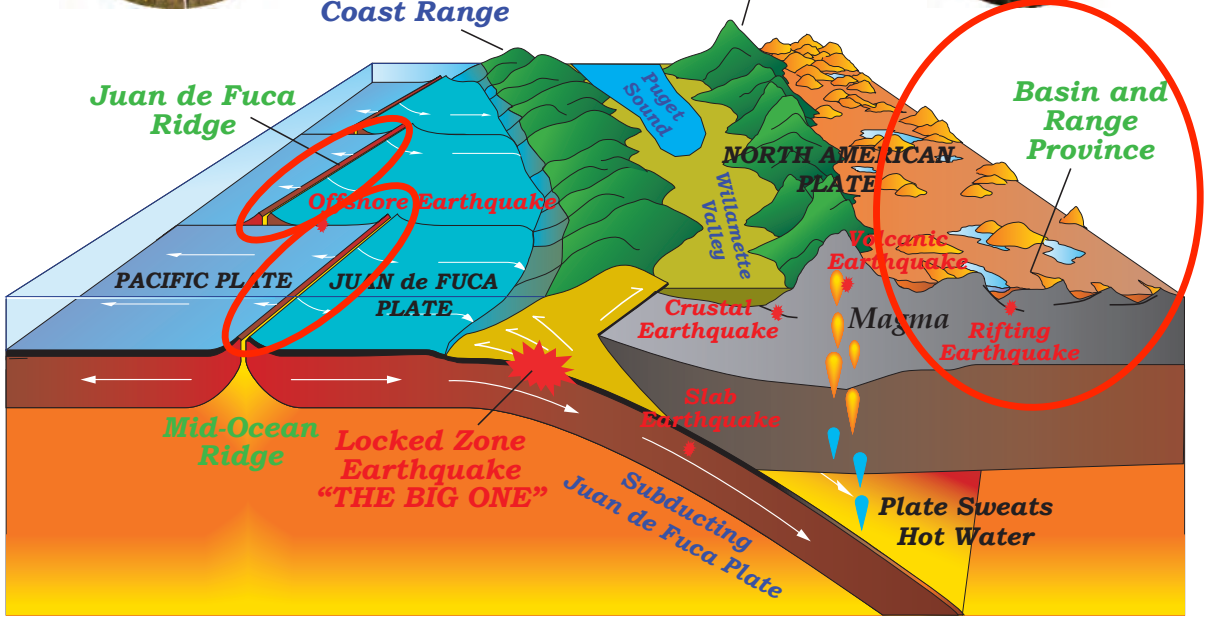


modified from Weaver and Shedlock, 1996

Divergent Plate Boundaries

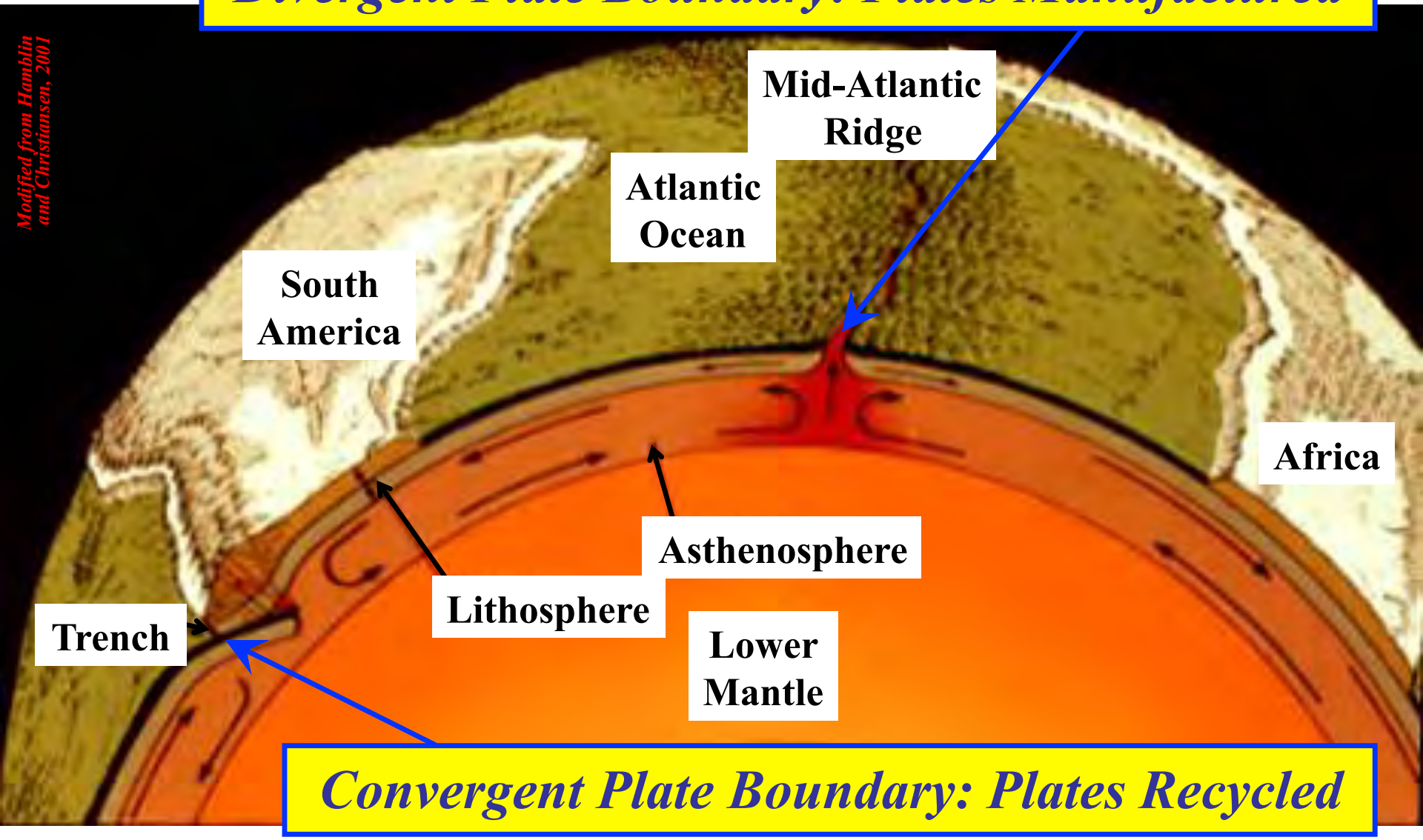
Plate Tectonics of the Pacific Northwest





Cascadia EarthScope Earthquake and Tsunami Education Program
http://ceetep.oregonstate.edu

Giant Re-Cycling Machine!! ☺



Andes Mountains, South America

Osorno volcano near Puerto Montt, Chile

http://whatonearth.olehnielsen.dk/volcanoes.asp

Activities: Binder p. 69 – "World Map of Plate Boundaries"

Subduction Zones rim the Pacific Ocean

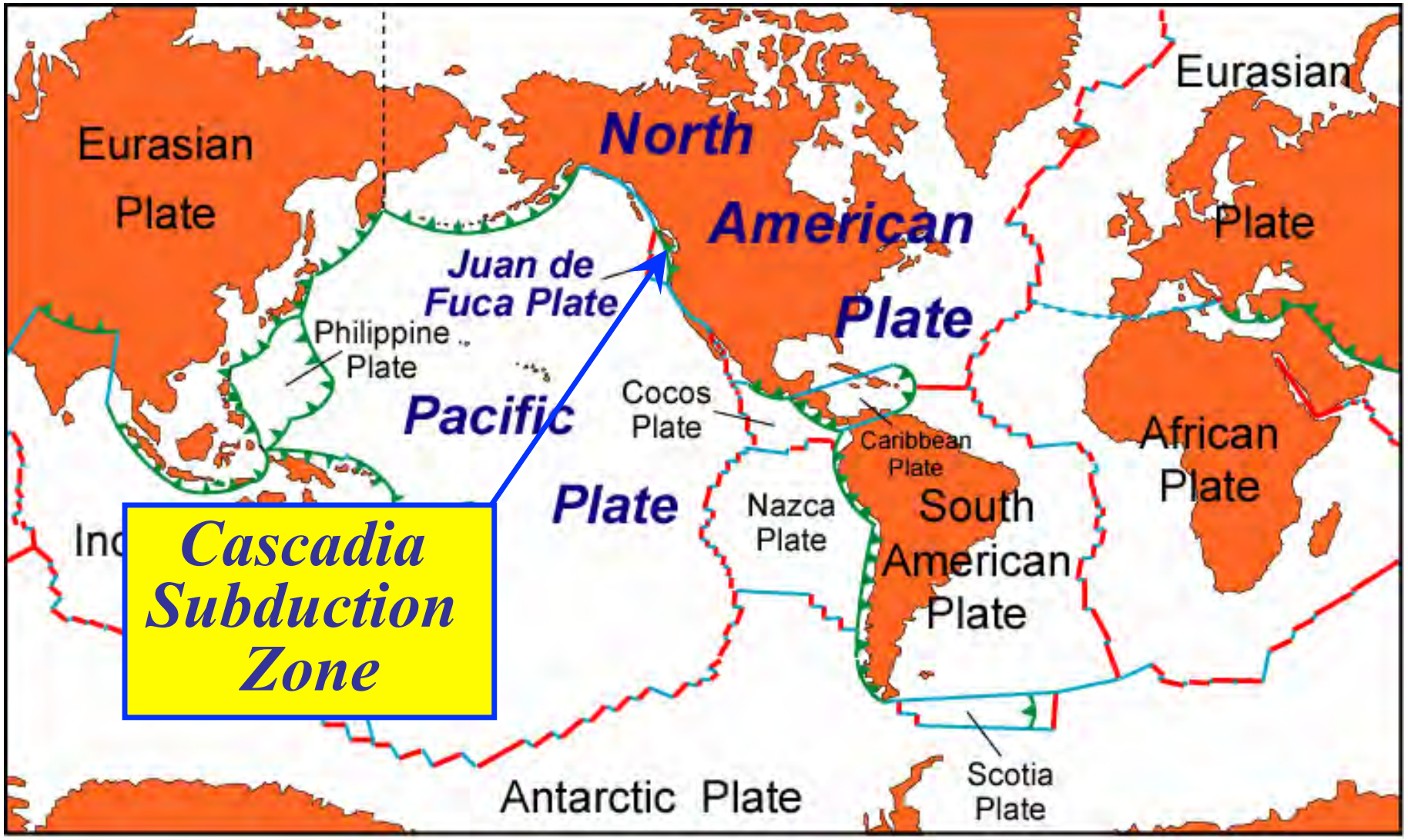
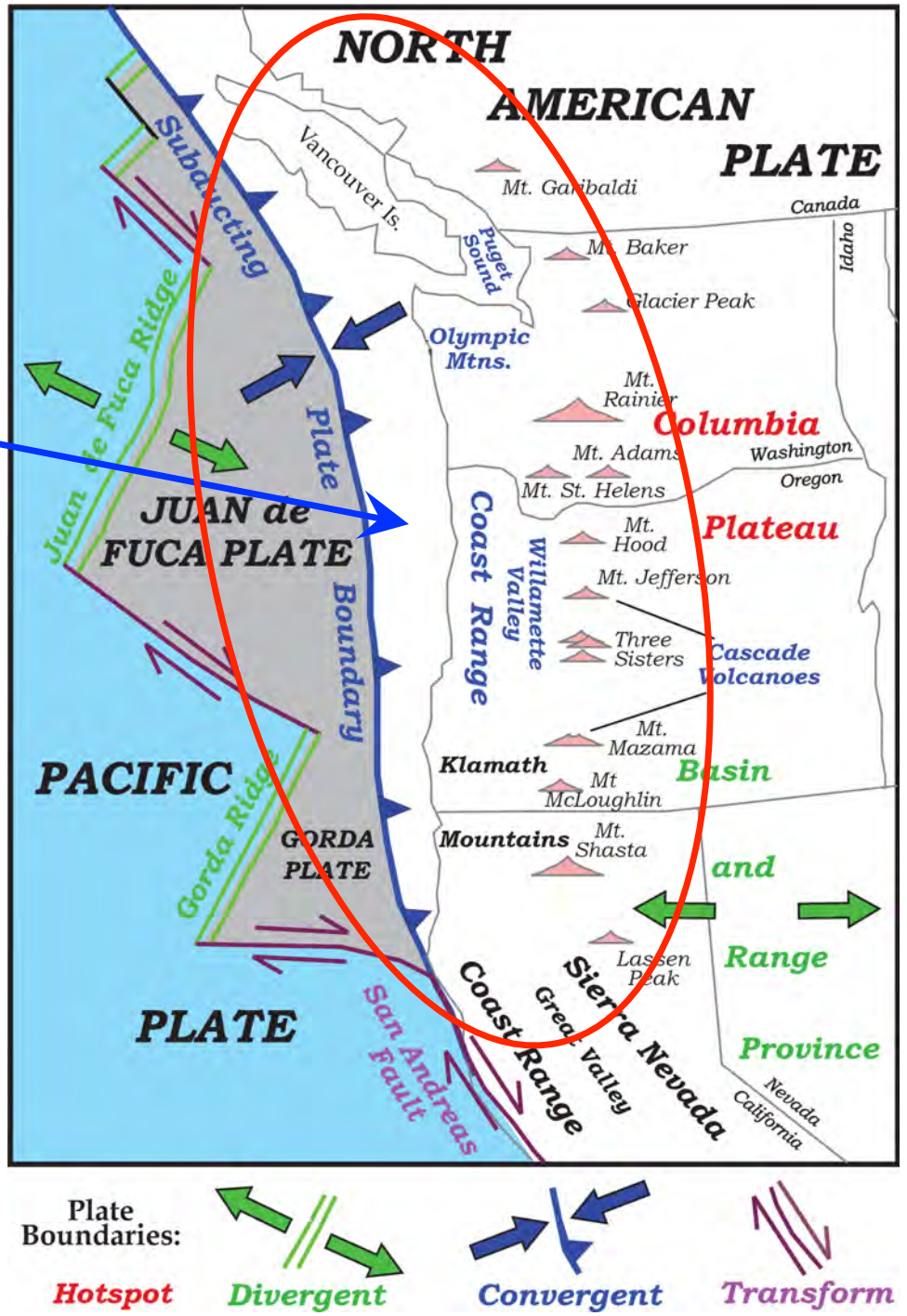


Plate Tectonics--Subduction Zone

Convergent Plate Boundary

Entire region is the "Cascadia Subduction Zone"



Coastal Ranges

1. Why are there two parallel mountain ranges in the Pacific Northwest?

2. Why are there earthquakes, tsunamis and volcanic eruptions?

Cascade Volcanoes

National Park Lands in the Pacific Northwest

Coastal Ranges

Layers Lifted out of the Sea

Cascade Mountains

Steep, Explosive Volcanoes

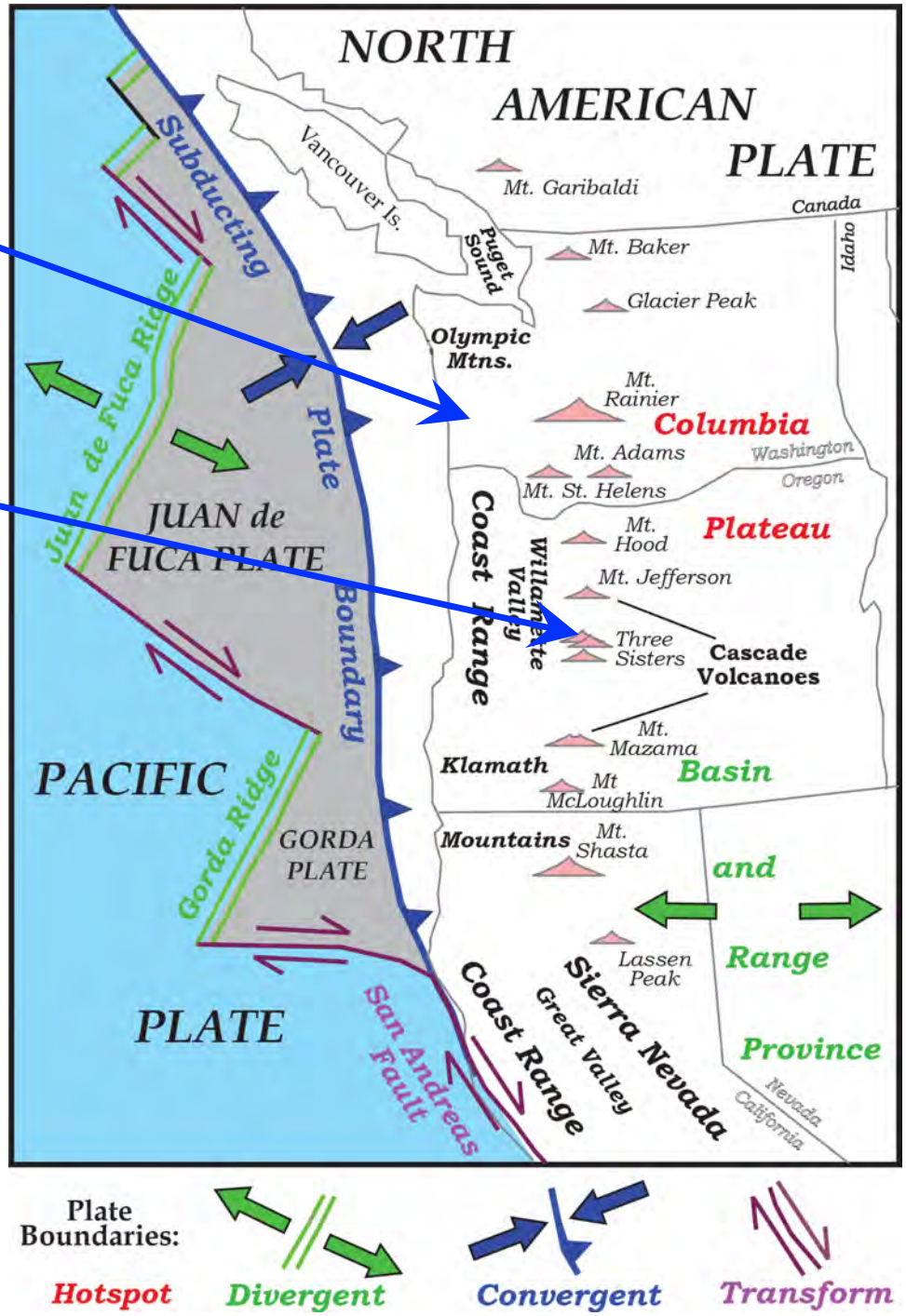
Mt. Rainier National Park, Washington

Robert J. Lillie

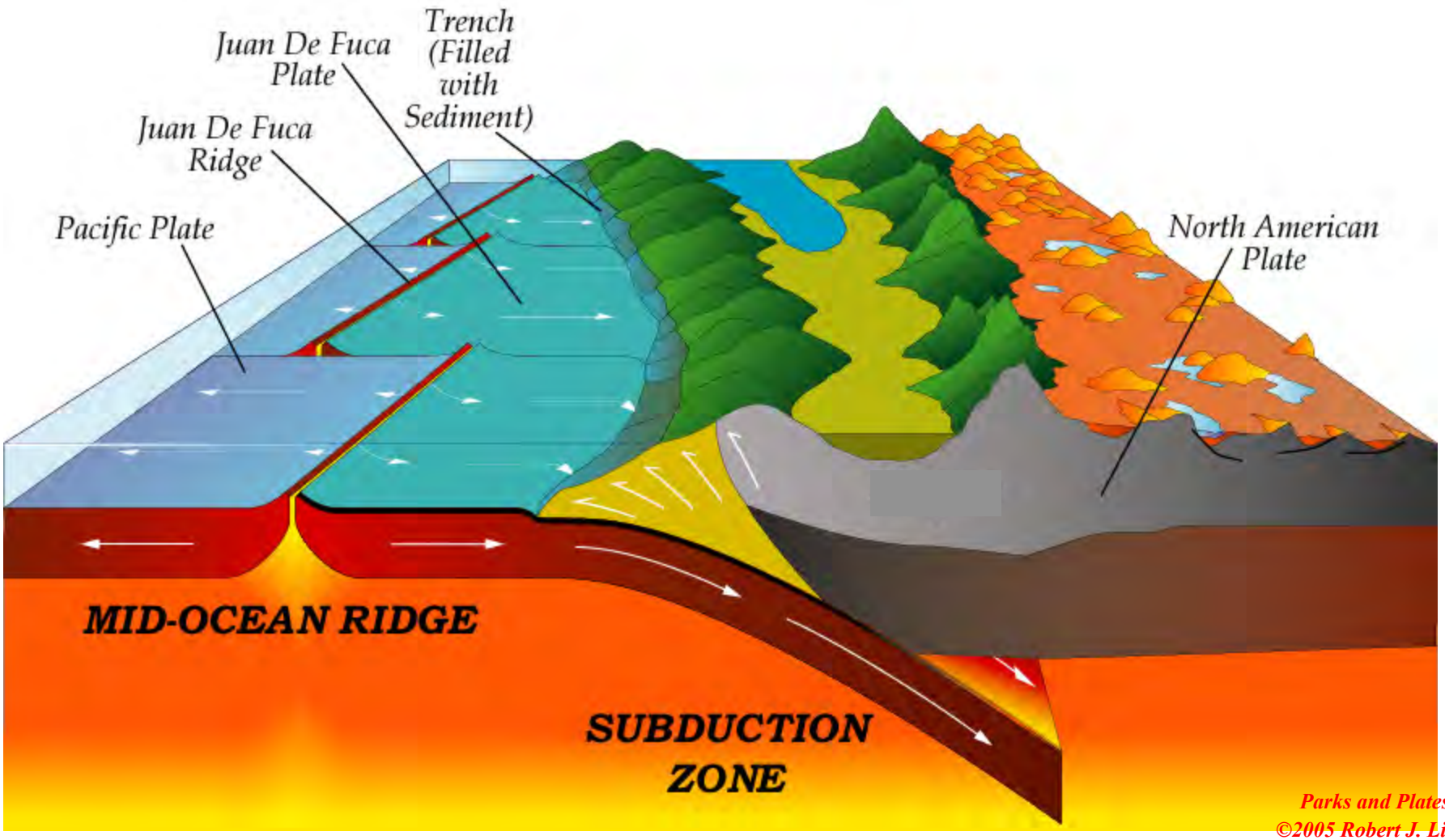
Coastal Ranges

Cascade Volcanoes

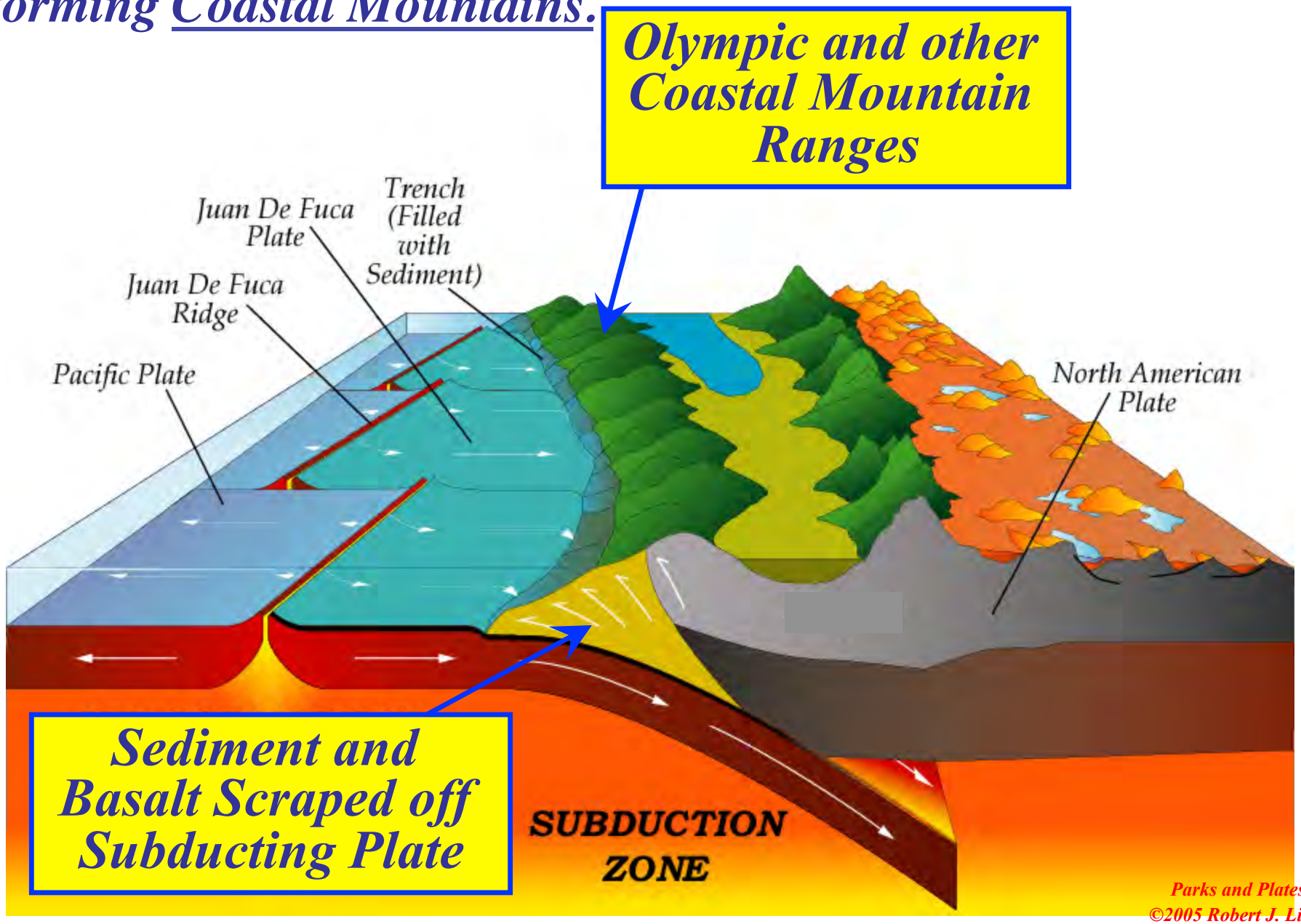
Subduction of the Juan de Fuca Plate forms the Coastal Ranges and Cascade Volcanoes



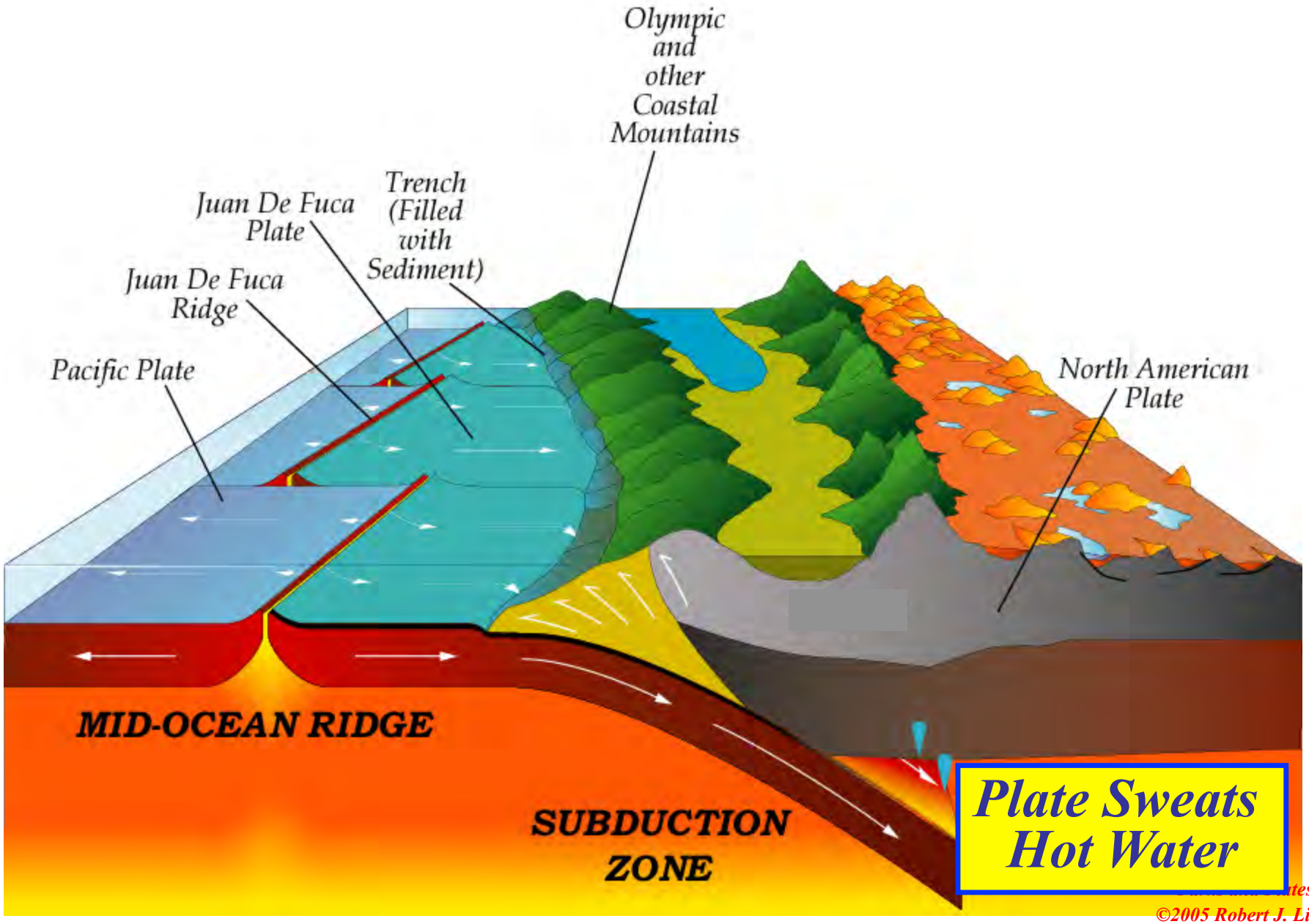
Subducting Juan de Fuca Plate forms two parallel mountain ranges in the Pacific Northwest.



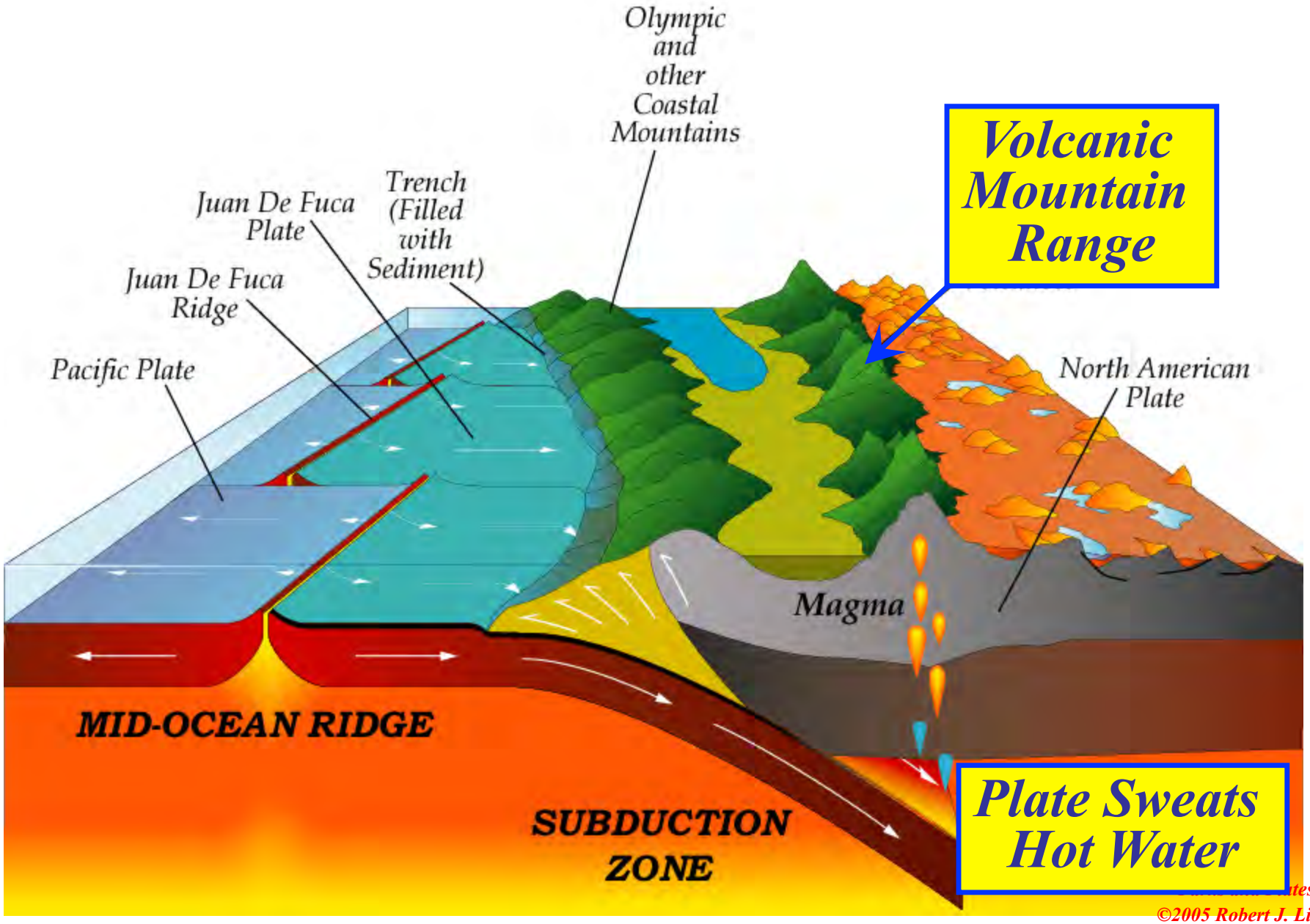
Oceanic sediment and basalt scraped off subducting plate, forming Coastal Mountains.



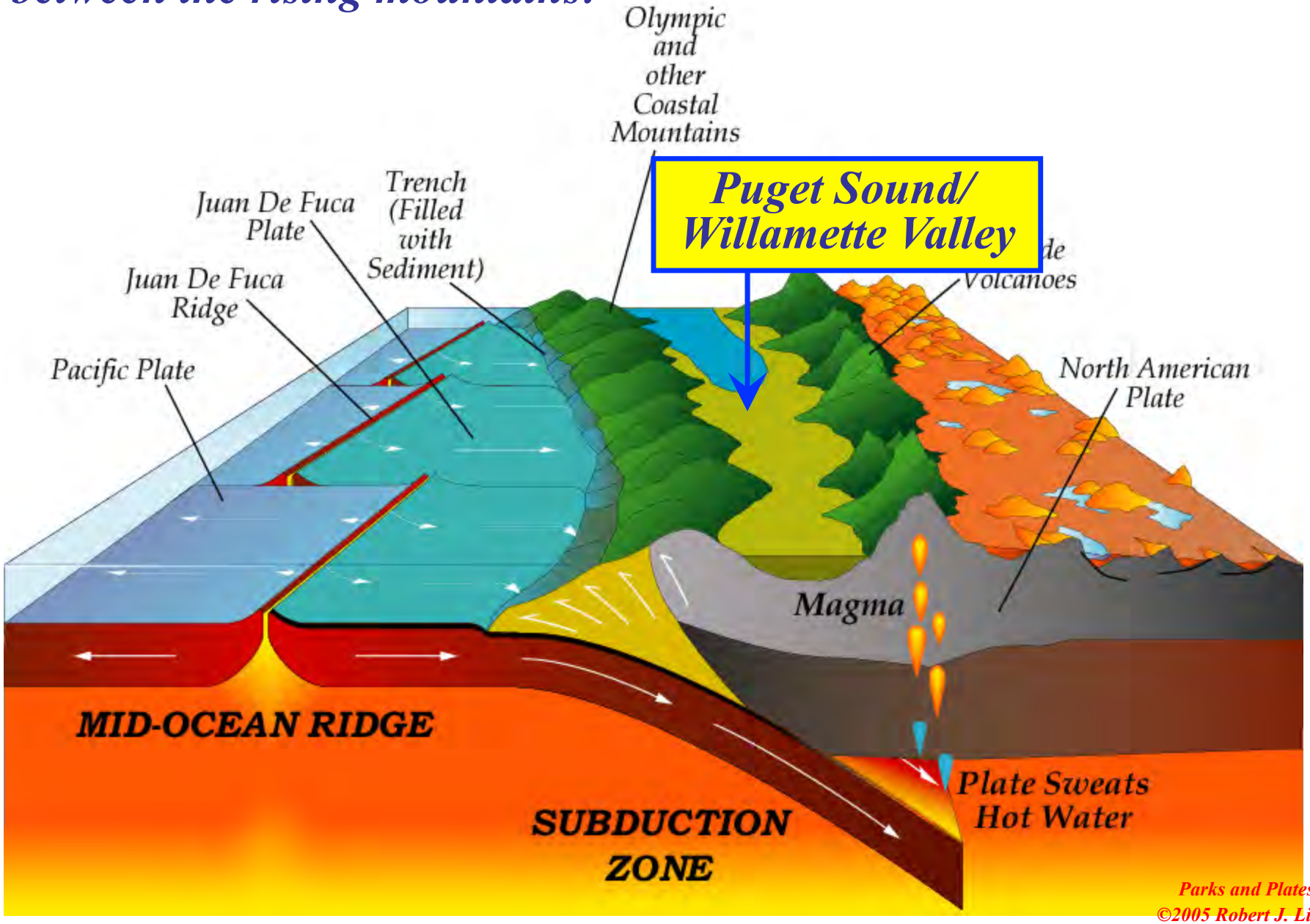
Subducting plate dehydrates, forming Cascade Volcanoes.



Subducting plate dehydrates, forming Cascade Volcanoes.

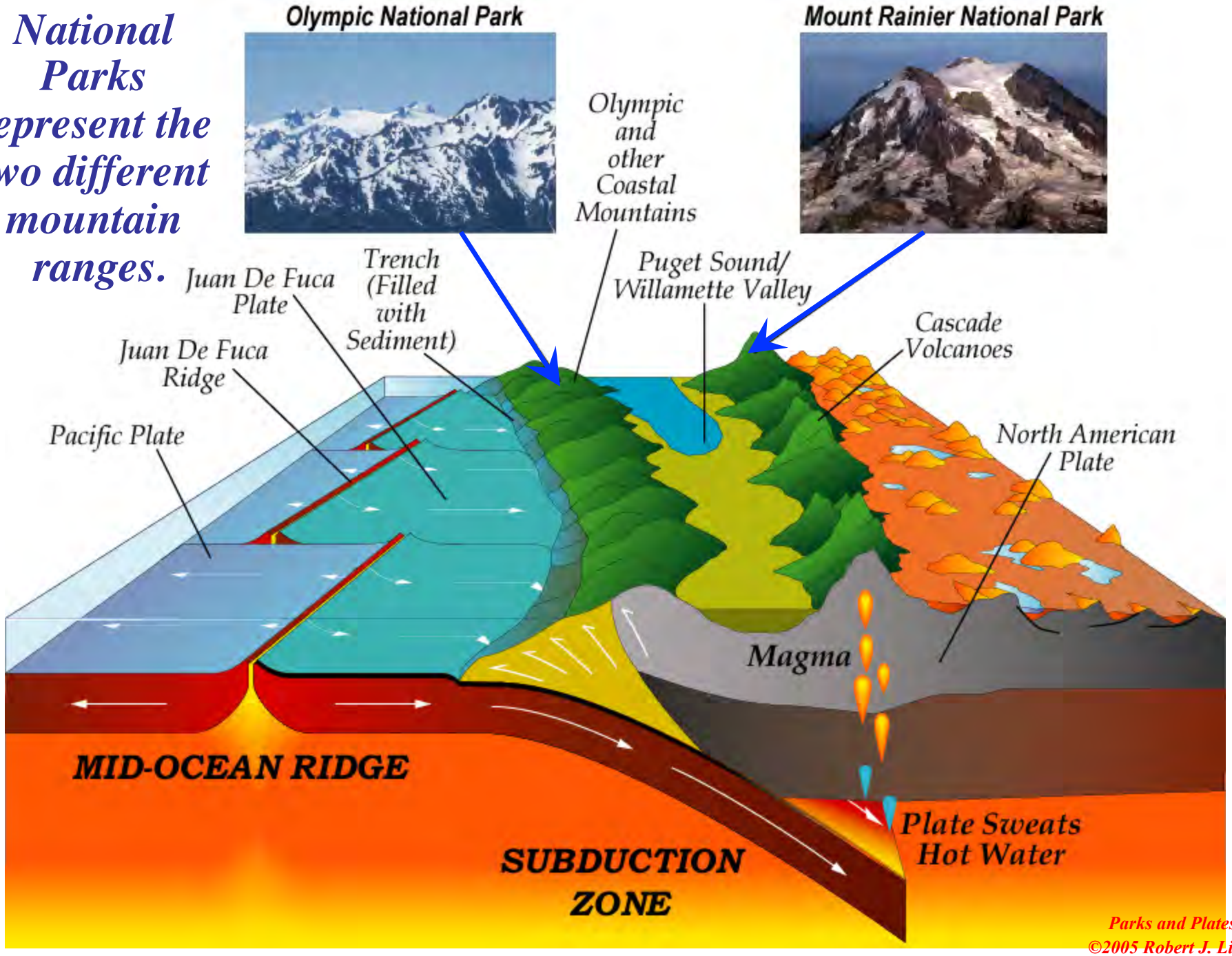


***Puget Sound* and the *Willamette Valley* are low-lying regions between the rising mountains.**



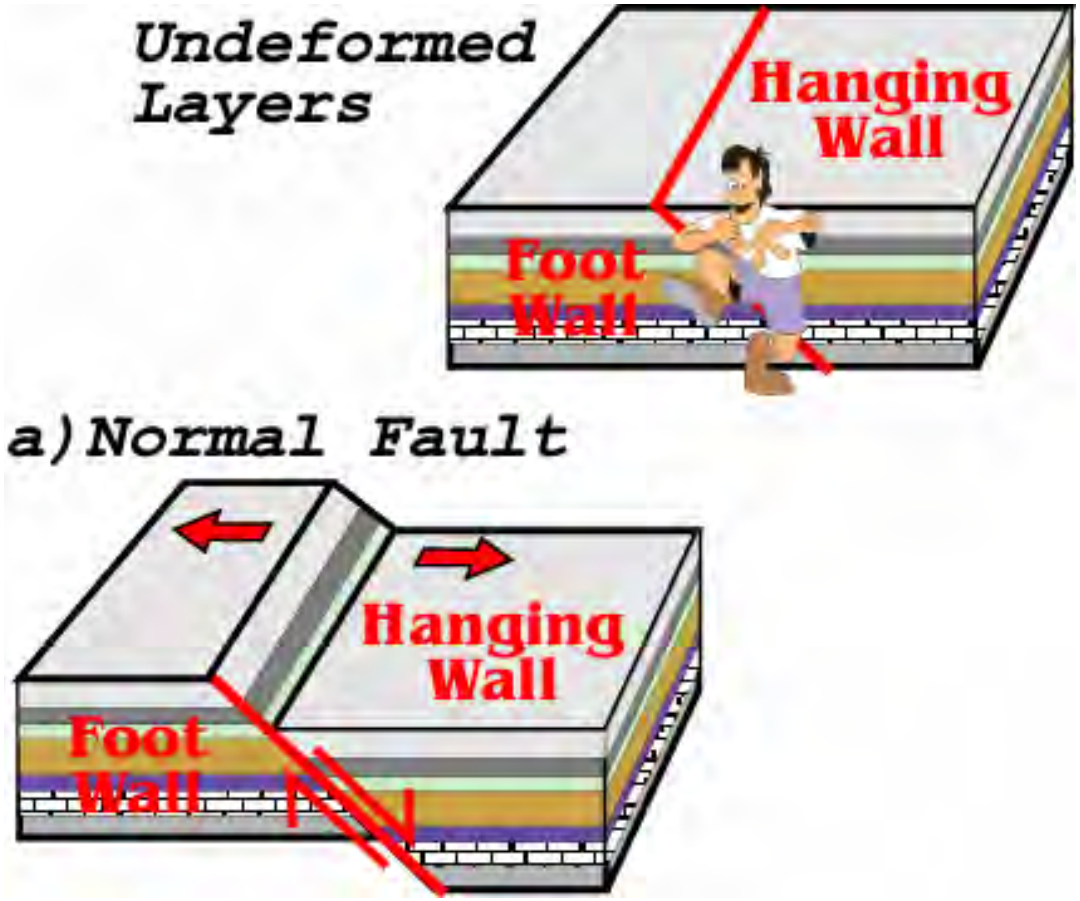
Robert J. Lillie
Bernard Garcia

National Parks represent the two different mountain ranges.

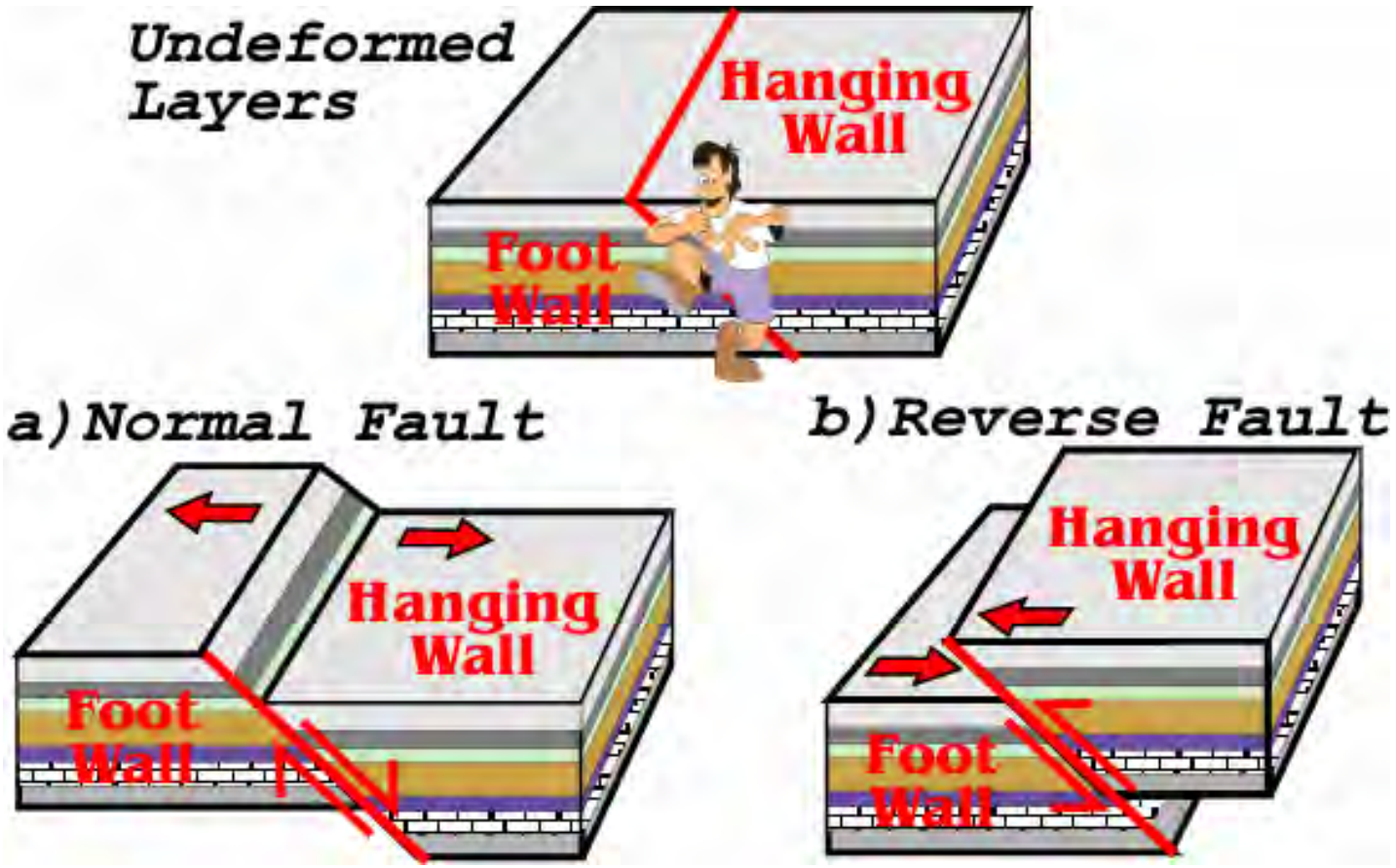


Robert J. Lillie
Bernard Garcia

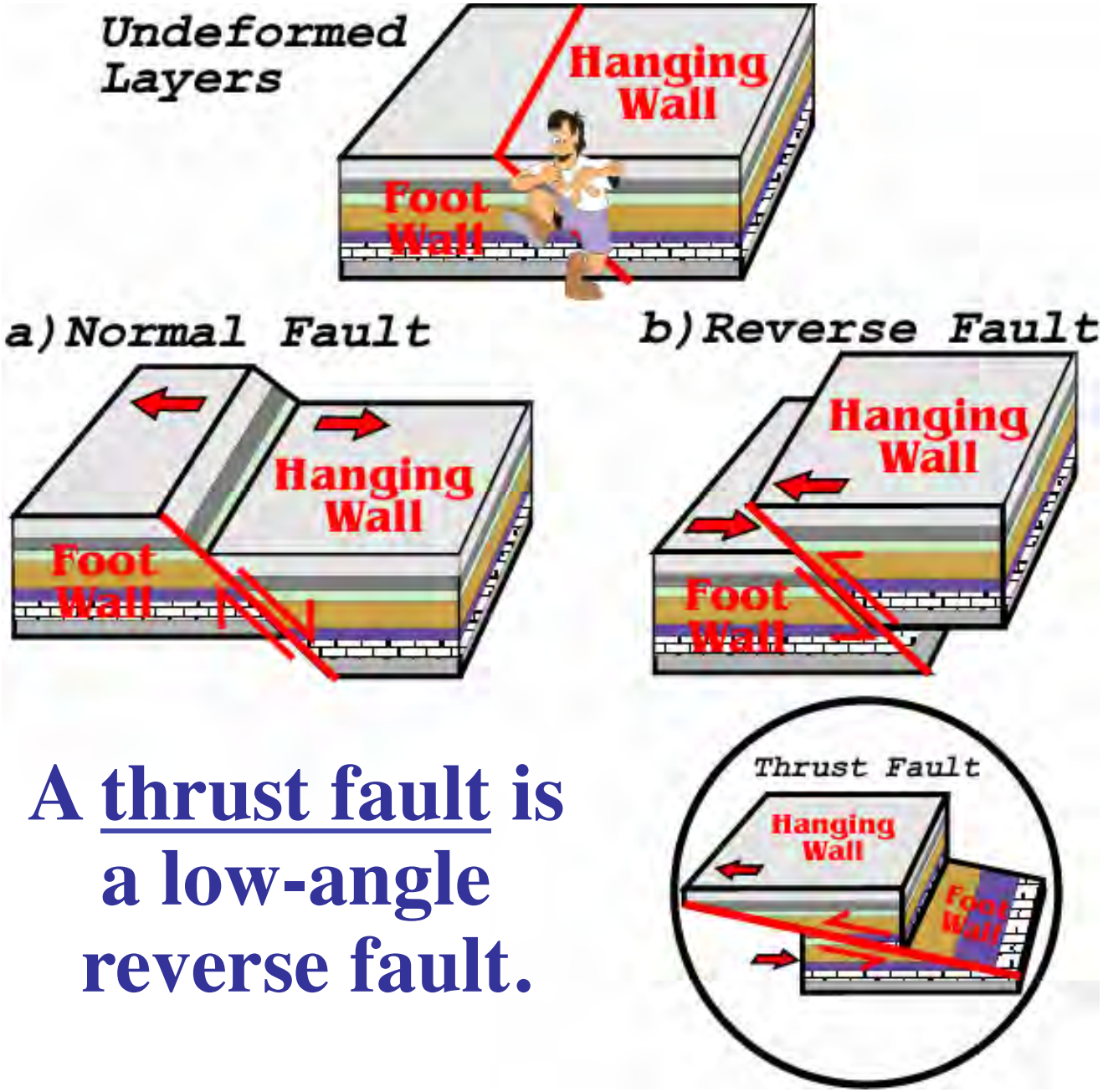
Activities: Binder p. 5 – "Foam Faults"



Activities: Binder p. 5 – "Foam Faults"



Activities: Binder p. 5 – "Foam Faults"

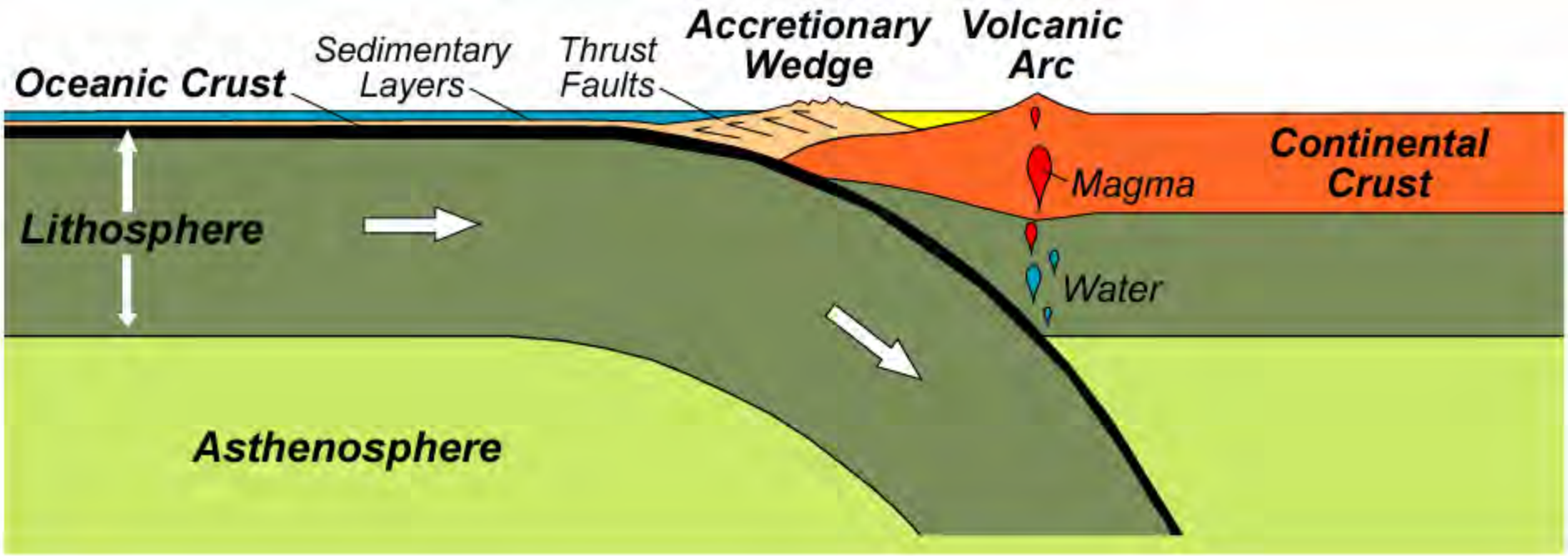


A thrust fault is a low-angle reverse fault.

Activities: Binder p. 5 – "Foam Faults"

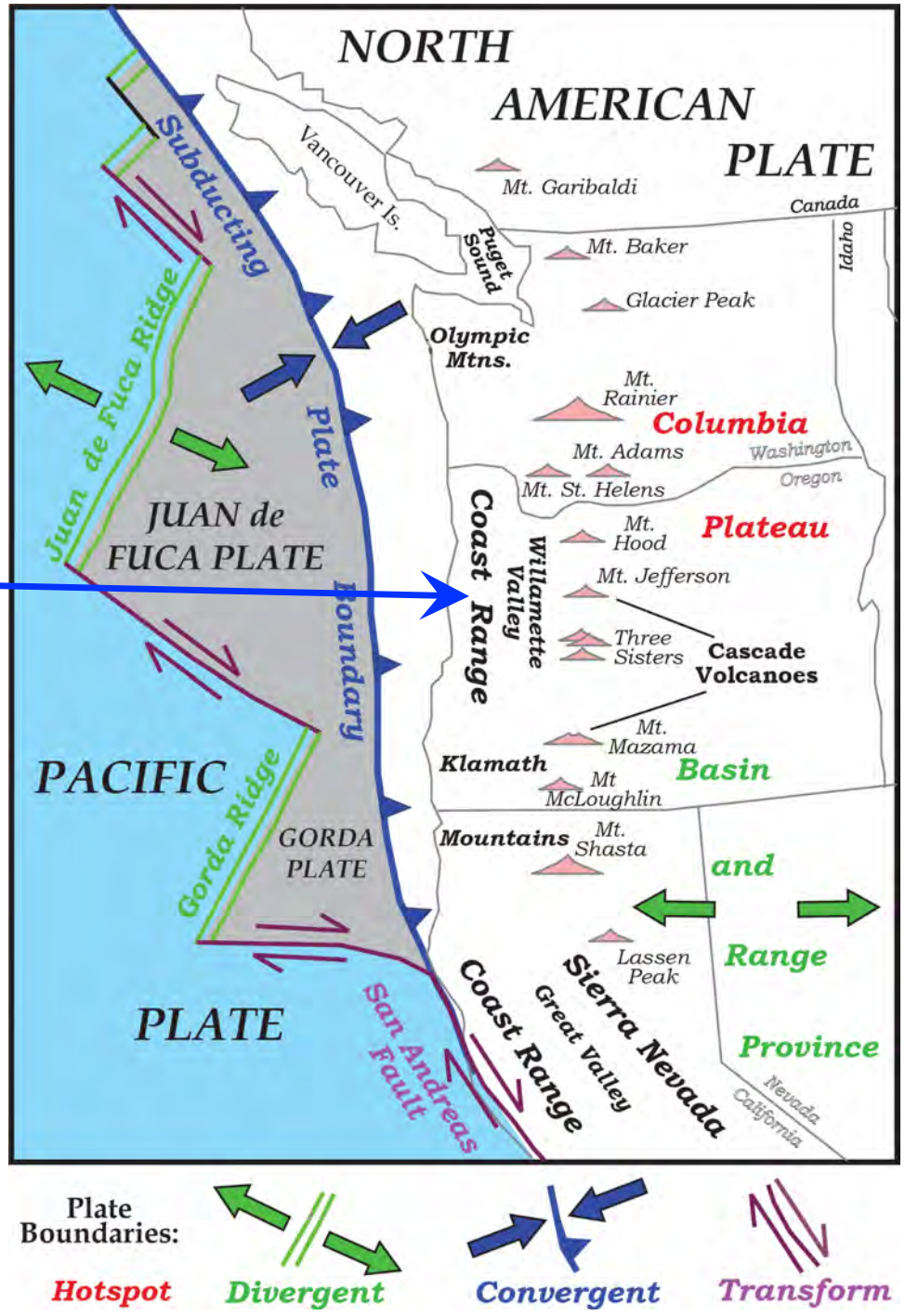
CONVERGENT PLATE BOUNDARY

Subduction Zone



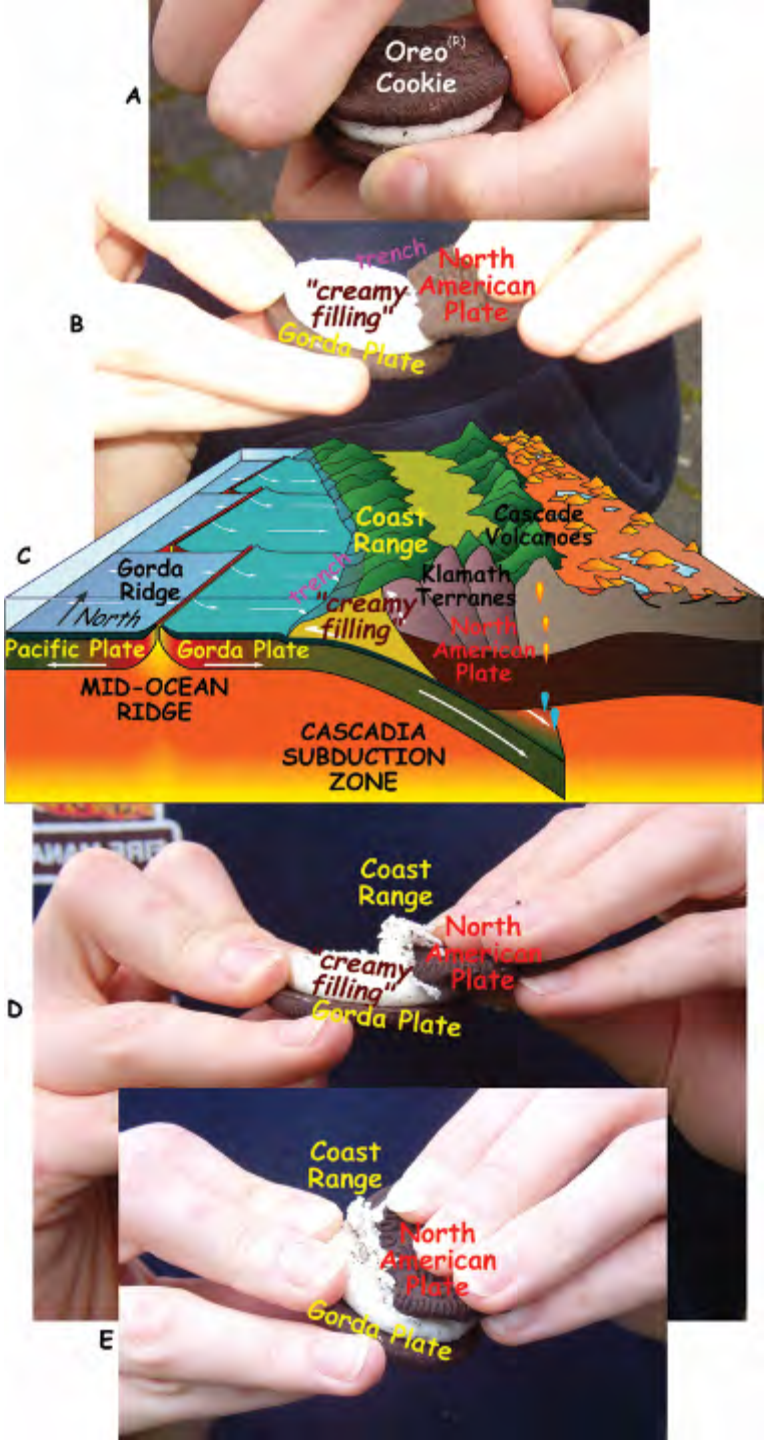
Compressional Forces Produce Reverse (Thrust) Faults

The Coast Range contains Basalt and Sedimentary Layers originally deposited on the Floor of the Ocean



Ranger Jen's Oreo Subduction Demo

Coast ranges are material scraped off the ocean floor.



Coastal Ranges

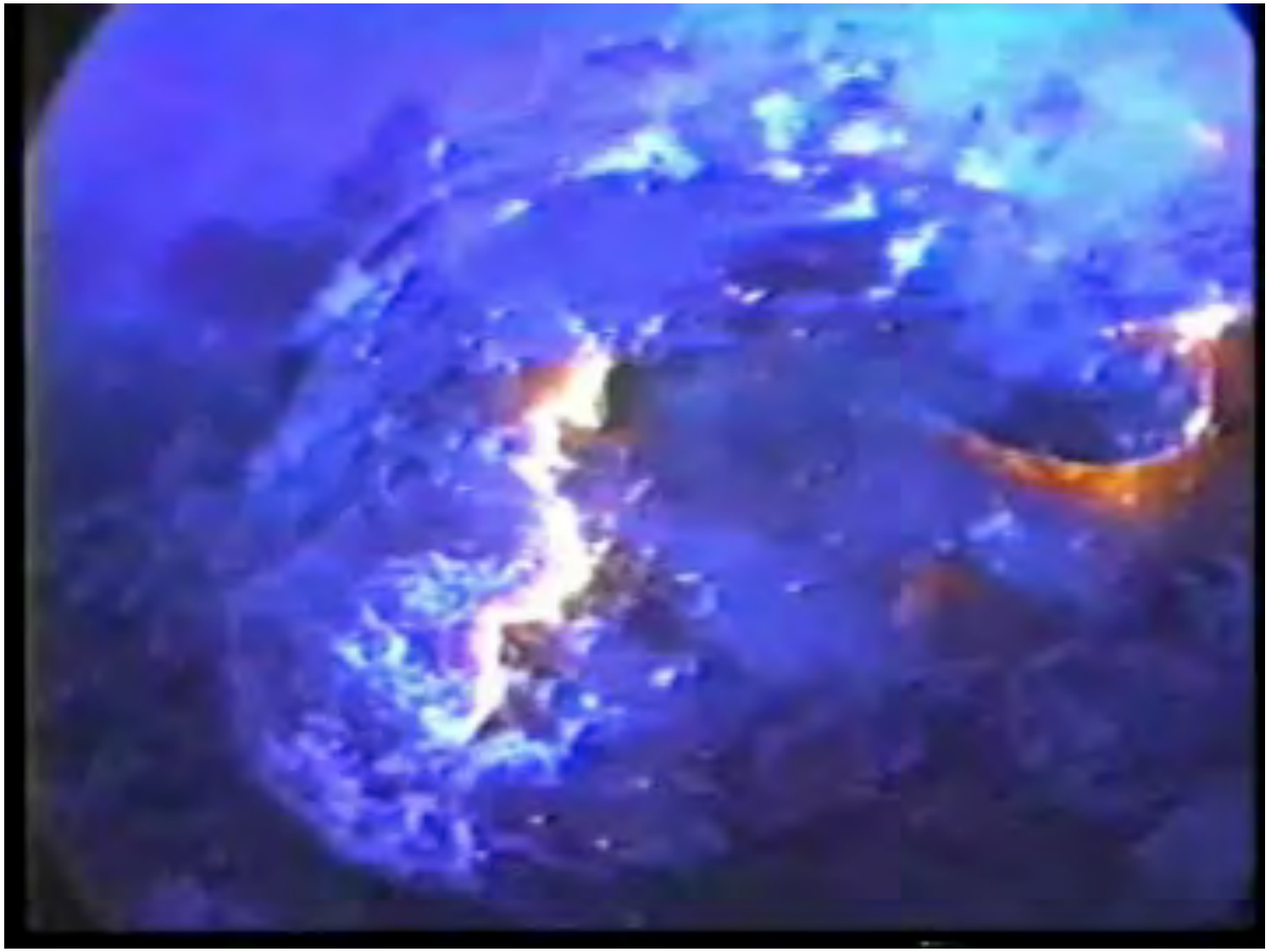
Layers Lifted out of the Sea

Olympic National Park, Washington

Hurricane Ridge Road

Olympic National Park, Washington

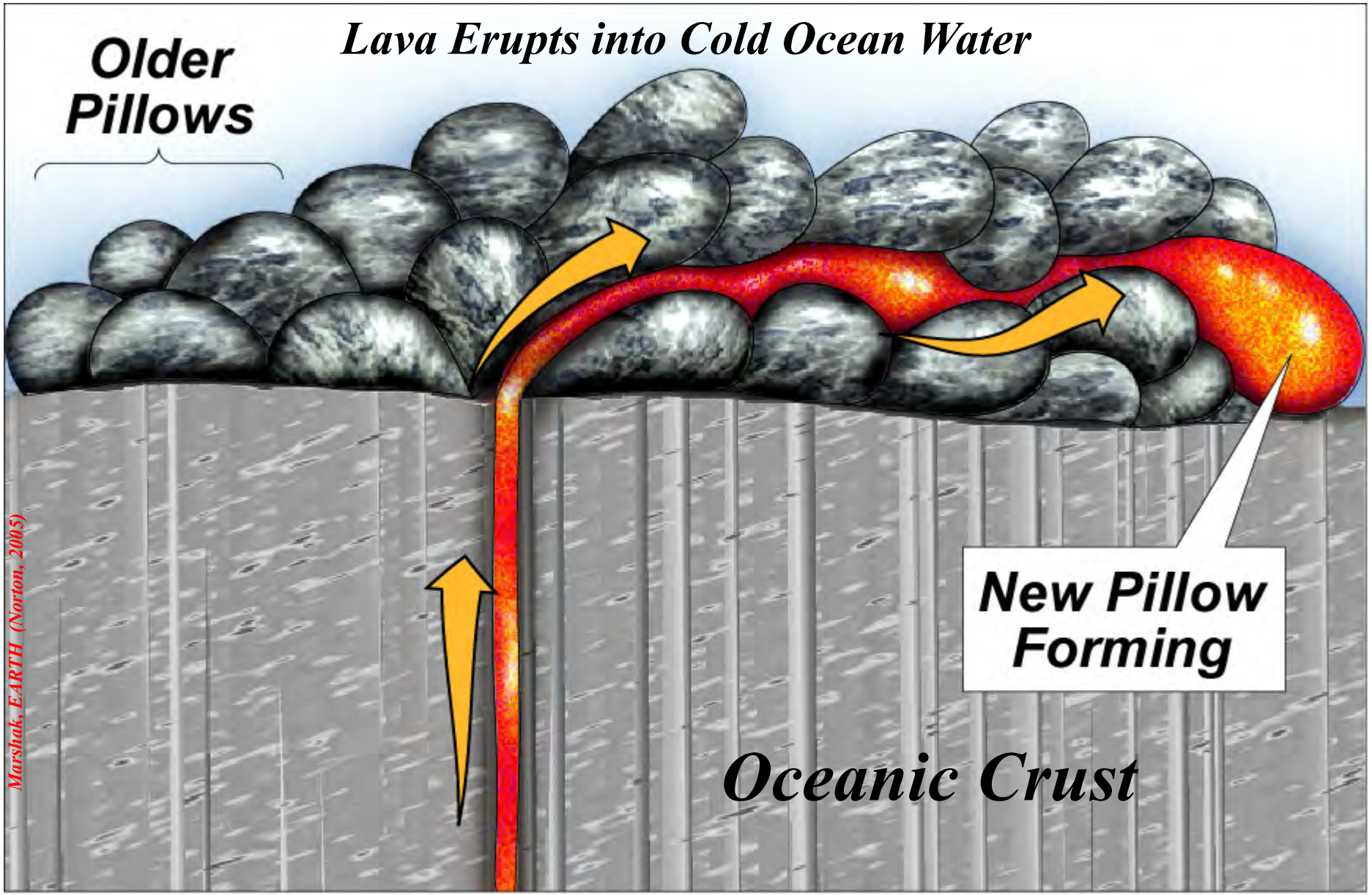
Formation of Pillow Lava

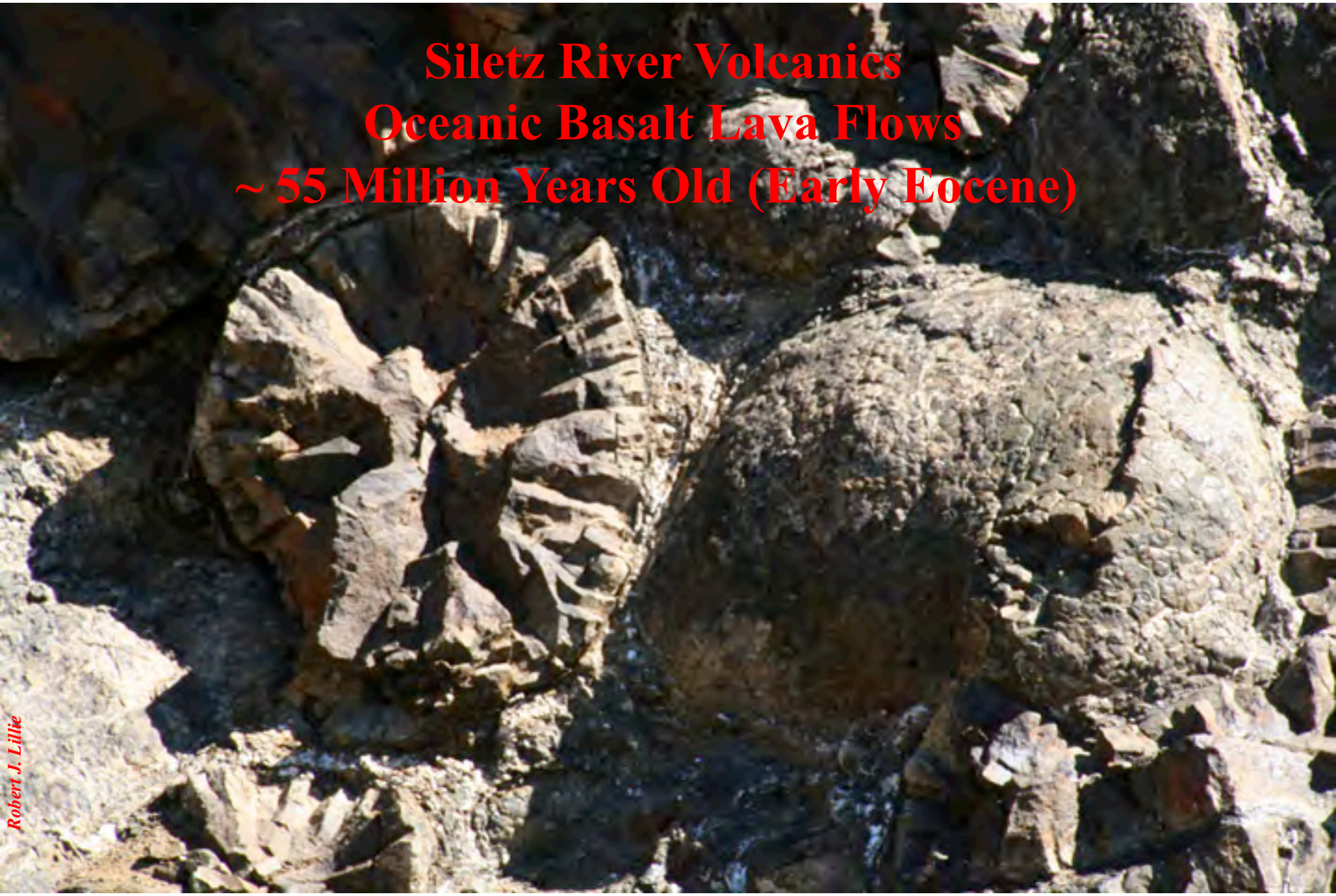


The formation of pillow lava in the deep ocean has never been observed, but it probably looks a lot like this. This movie shows pillow lava flowing underwater off the coast of Hawaii, after it was erupted on land and flowed into the ocean. Video footage from the movie "Pele Meets the Sea" courtesy of Richard Pyle (deepreef@bishopmuseum.org) at Lava Video Productions.

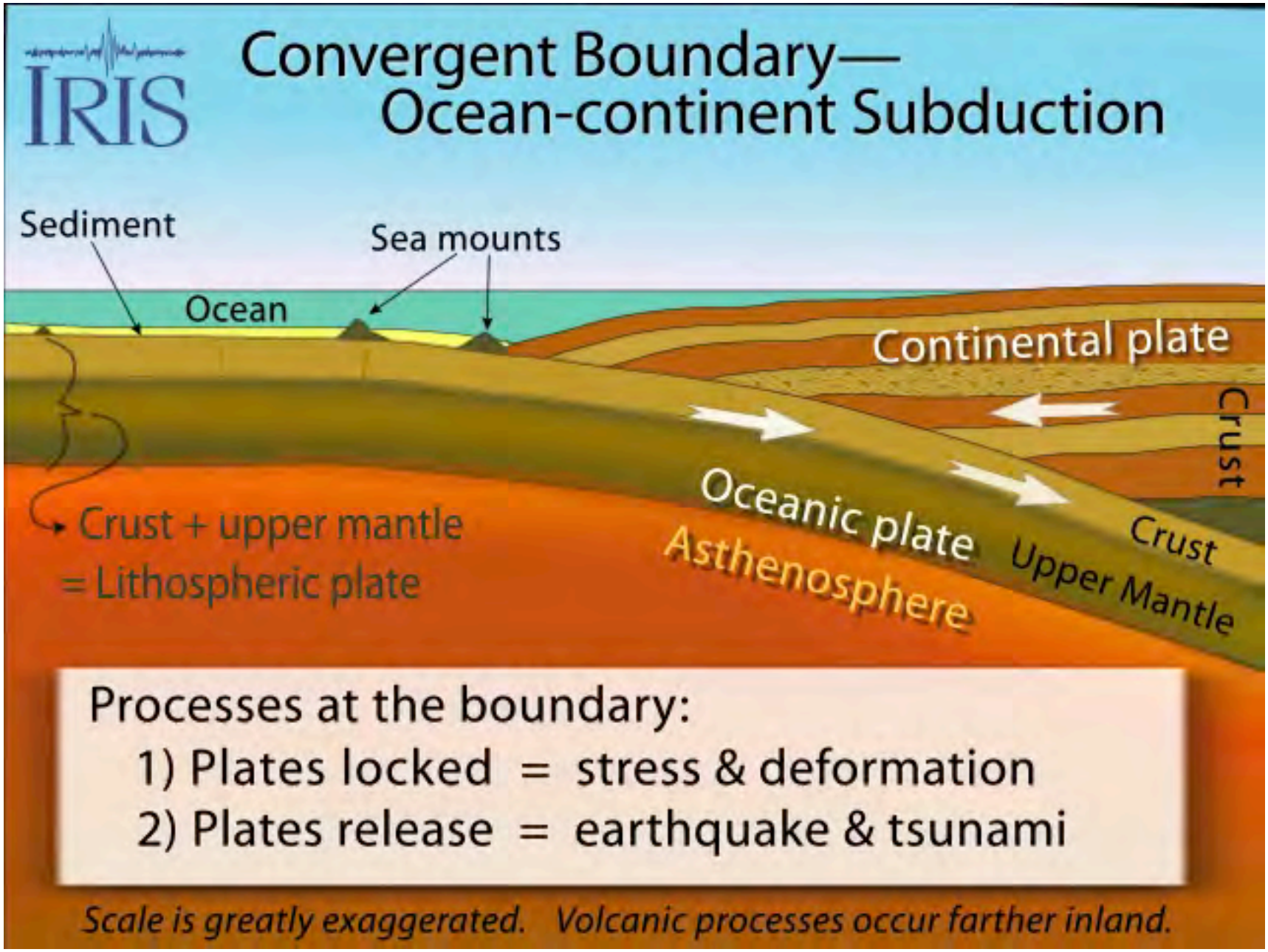
http://oceanexplorer.noaa.gov/explorations/04fire/background/volcanism/media/pillow_lava_video.html

Formation of Pillow Lava





Marys Peak Recreation Area, Oregon



www.iris.edu (Animation by Jenda Johnson - Time 1:15)

Coastal Ranges

1. Why are there two parallel mountain ranges in the Pacific Northwest?

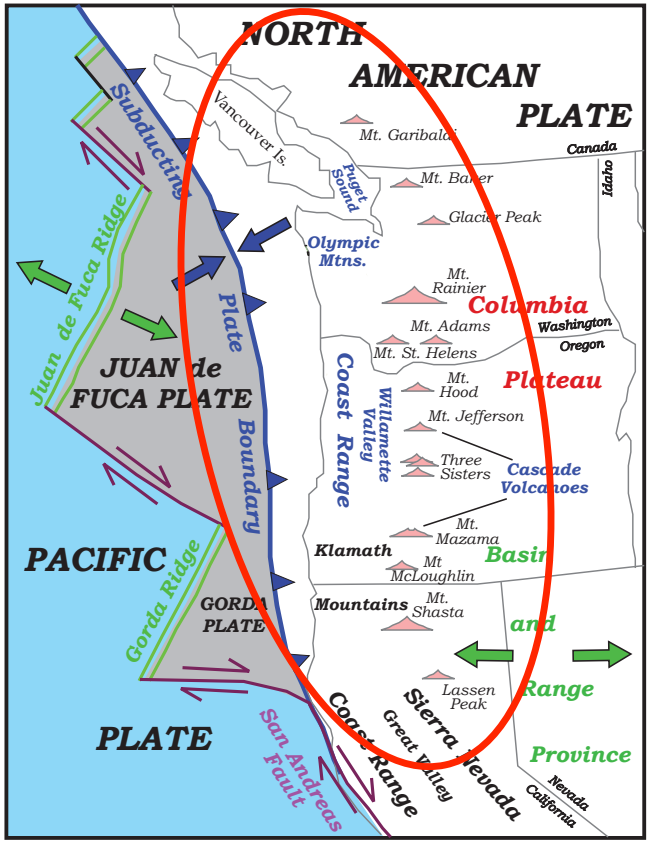
2. Why are there earthquakes, tsunamis and volcanic eruptions?

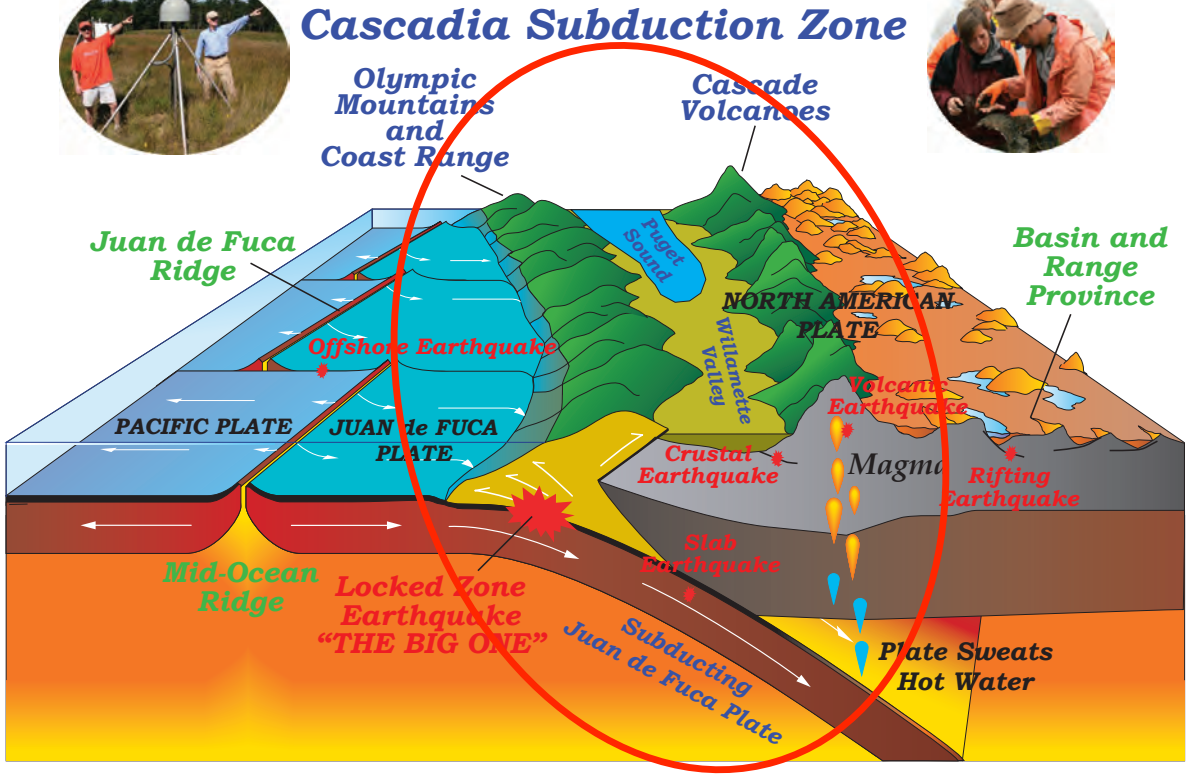
Cascade Volcanoes

National Park Lands in the Pacific Northwest

Convergent Plate Boundary

Plate Tectonics of the Pacific Northwest



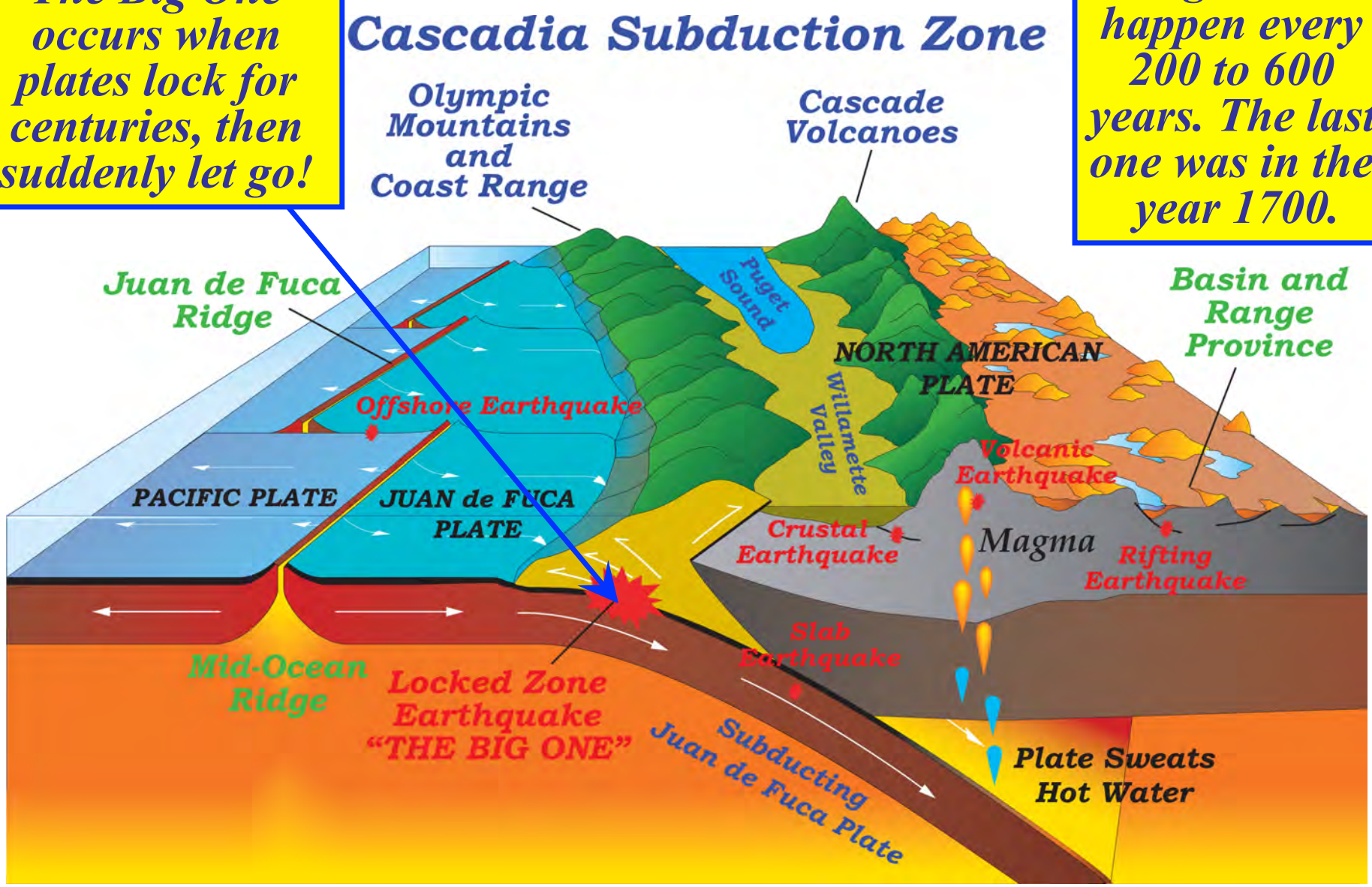


Cascadia EarthScope Earthquake and Tsunami Education Program

http://ceetep.oregonstate.edu

"The Big One" occurs when plates lock for centuries, then suddenly let go!

Big Ones happen every 200 to 600 years. The last one was in the year 1700.



Four Types of Earthquakes in Cascadia Subduction Zone

1) Slab Earthquakes:

- *Within Juan de Fuca Plate*
- *Up to 40 miles (60 km) depth*
- *Up to Magnitude 7*

2) Locked Zone (Mega-Thrust) Earthquakes:

- *Between Juan de Fuca and North American Plates*
- *5 - 10 miles (8 - 15 km) depth*
- *Up to Magnitude 9*

3) Upper Plate Earthquakes:

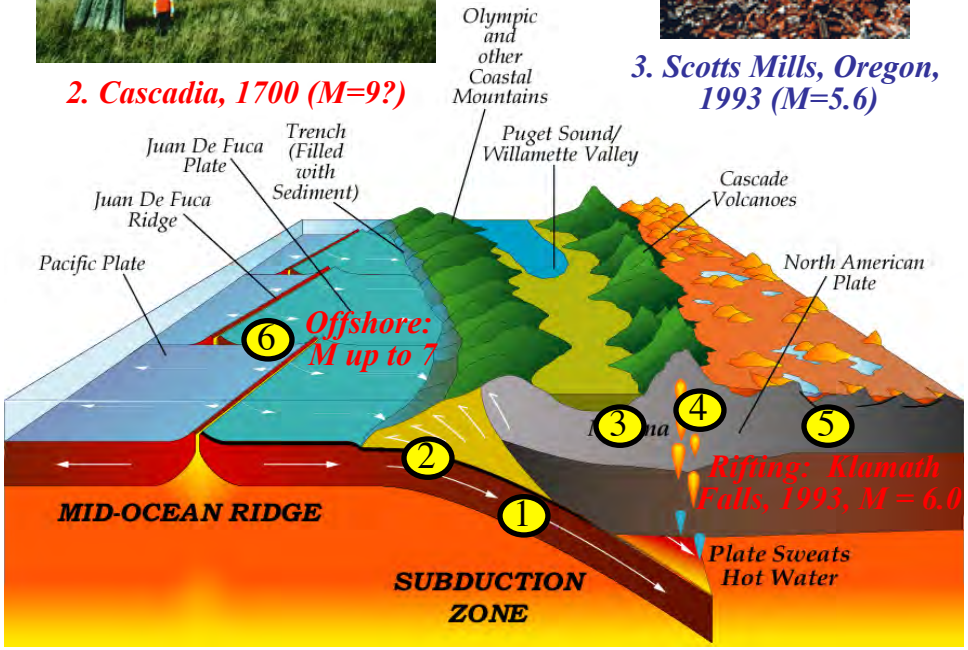
- *Within North American Plate*
- *1 - 10 miles (2 - 15 km) depth*
- *Up to Magnitude 7*

4) Volcanic Earthquakes:

- *From magma shallowing beneath Cascade volcanoes*
- *1 - 5 miles (2 - 10 km) depth*
- *Up to Magnitude 5.5*

2. Cascadia, 1700 (M=9?)

3. Scotts Mills, Oregon, 1993 (M=5.6)



1. Nisqually, Washington, 2001 (M=6.9)

4. Mt. St. Helens, Washington, 1980 (M=5.5)

Olympic National Park, Washington

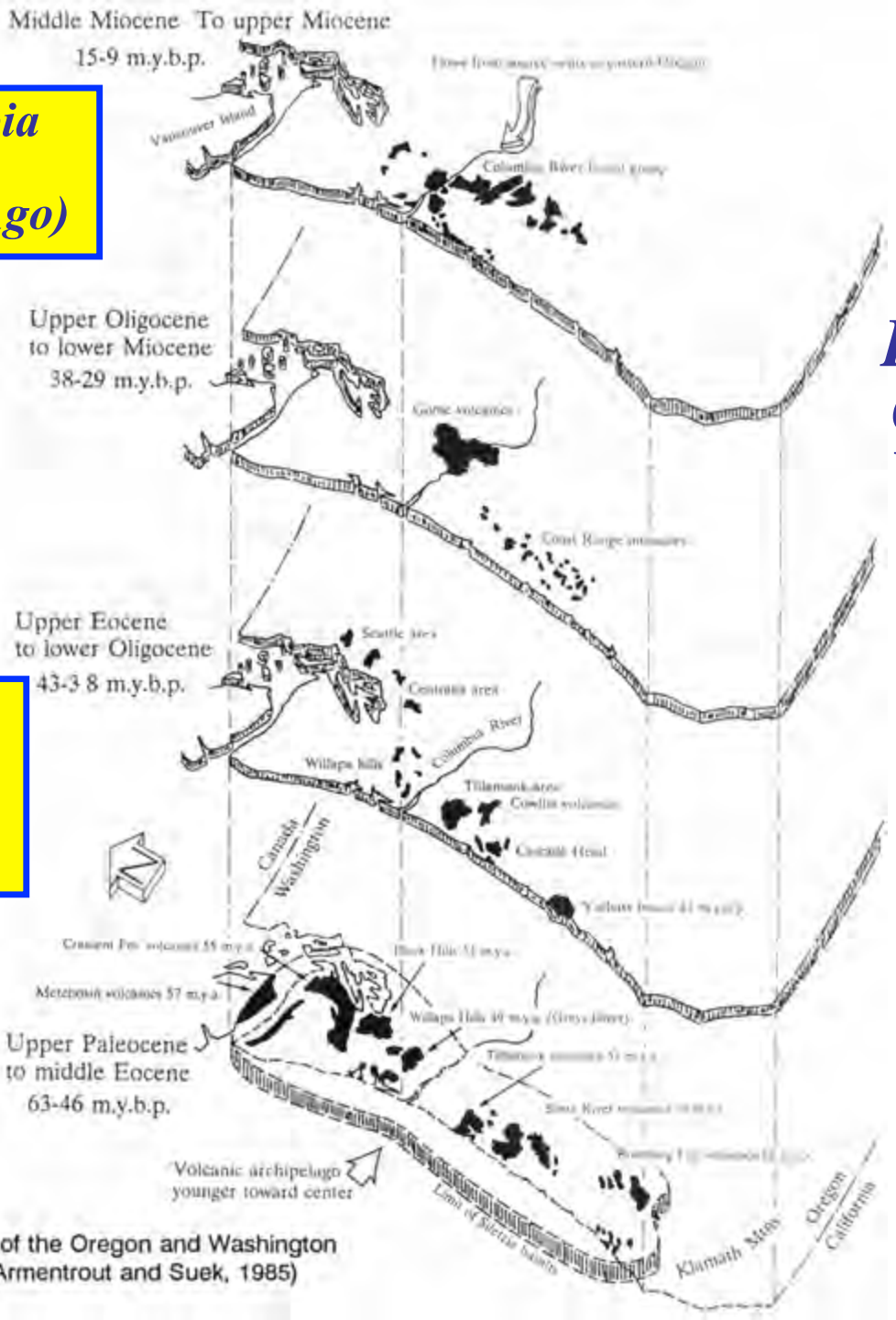
What about these <u>younger</u> lava flows?

Only 9 – 15 million years old

Age of Basalt along Oregon and Washington Coasts

Basalt from Columbia Plateau (15-9 Million Years Ago)

Basalt from Ocean Realm (63-29 Million Years Ago)



Volcanic rocks of the Oregon and Washington Coast Range (Armentrout and Suek, 1985)

Orr, Orr, and Baldwin, "Geology of Oregon," 4th Edition, 1992

Hotspot

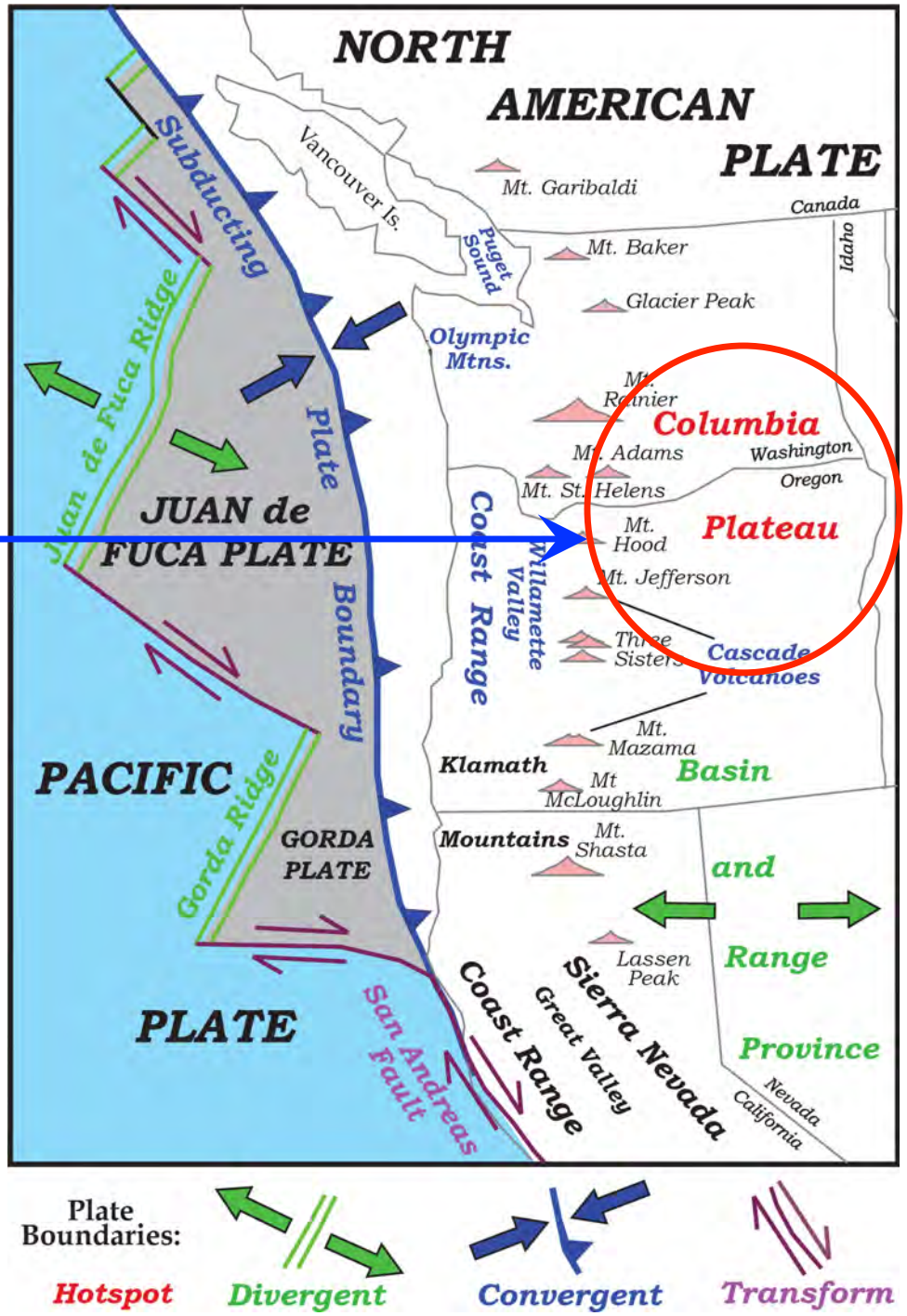
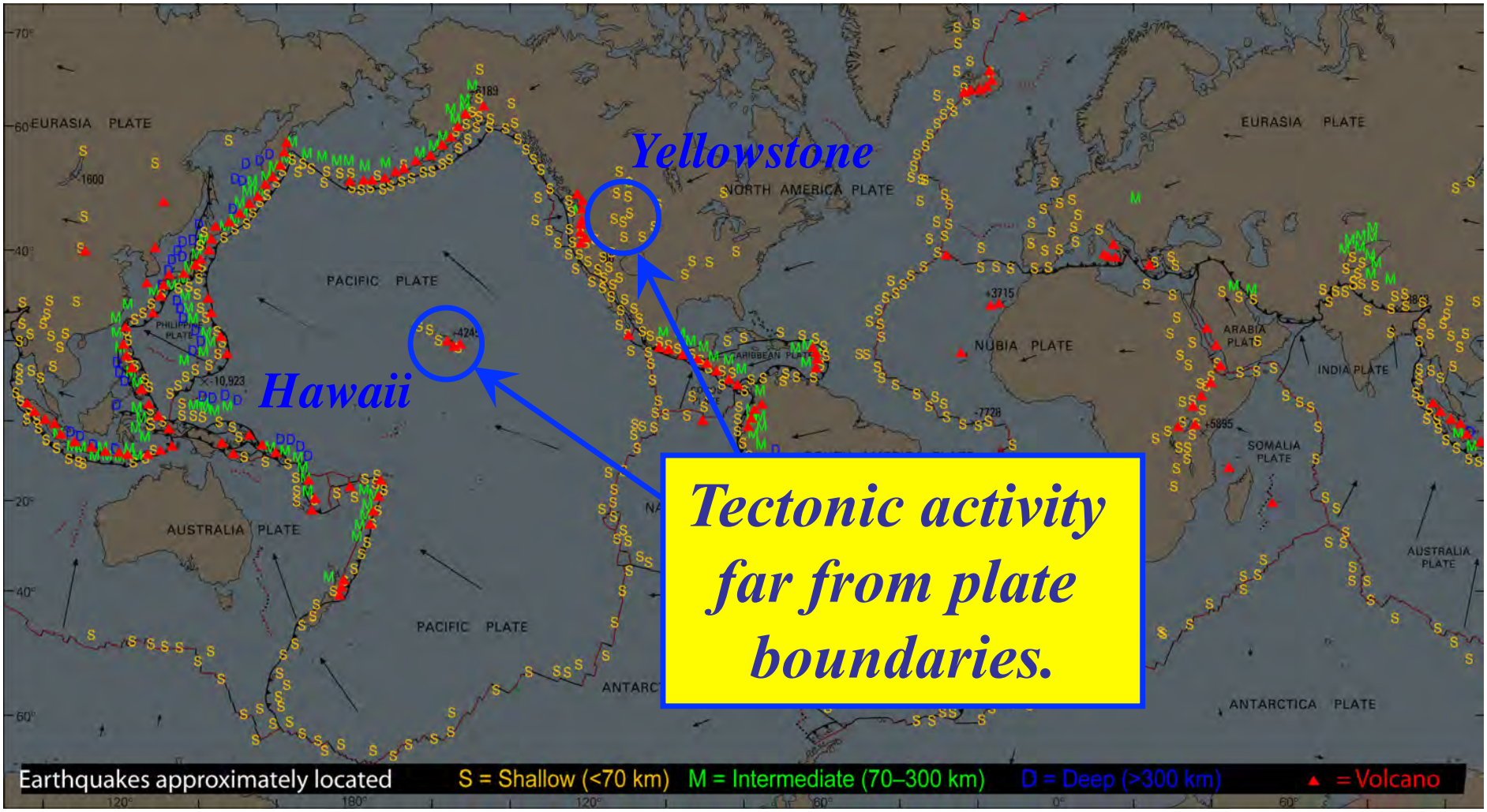

NORTH
AMERICAN
PLATE
Vancouver Is.
Mt. Garibaldi
Canada
Puget Sound
Mt. Baker
Idaho
Glacier Peak
Olympic Mtns.
Mt. Rainier
Columbia
Plateau
Mt. Adams
Washington
Oregon
Mt. St. Helens
Mt. Hood
Mt. Jefferson
Three Sisters
Cascade Volcanoes
Willamette Valley
Coast Range
Mt. Mazama
Klamath
Basin
Mt McLoughlin
Mountains
Mt. Shasta
and
Range
Lassen Peak
Province
Nevada
California
Sierra Nevada
Great Valley
Coast Range
San Andreas Fault
Subducting
Juan de Fuca Ridge
Plate
JUAN de FUCA PLATE
Boundary
PACIFIC
Gorda Ridge
GORDA PLATE
PLATE
Plate Boundaries:
Hotspot
Divergent
Convergent
Transform

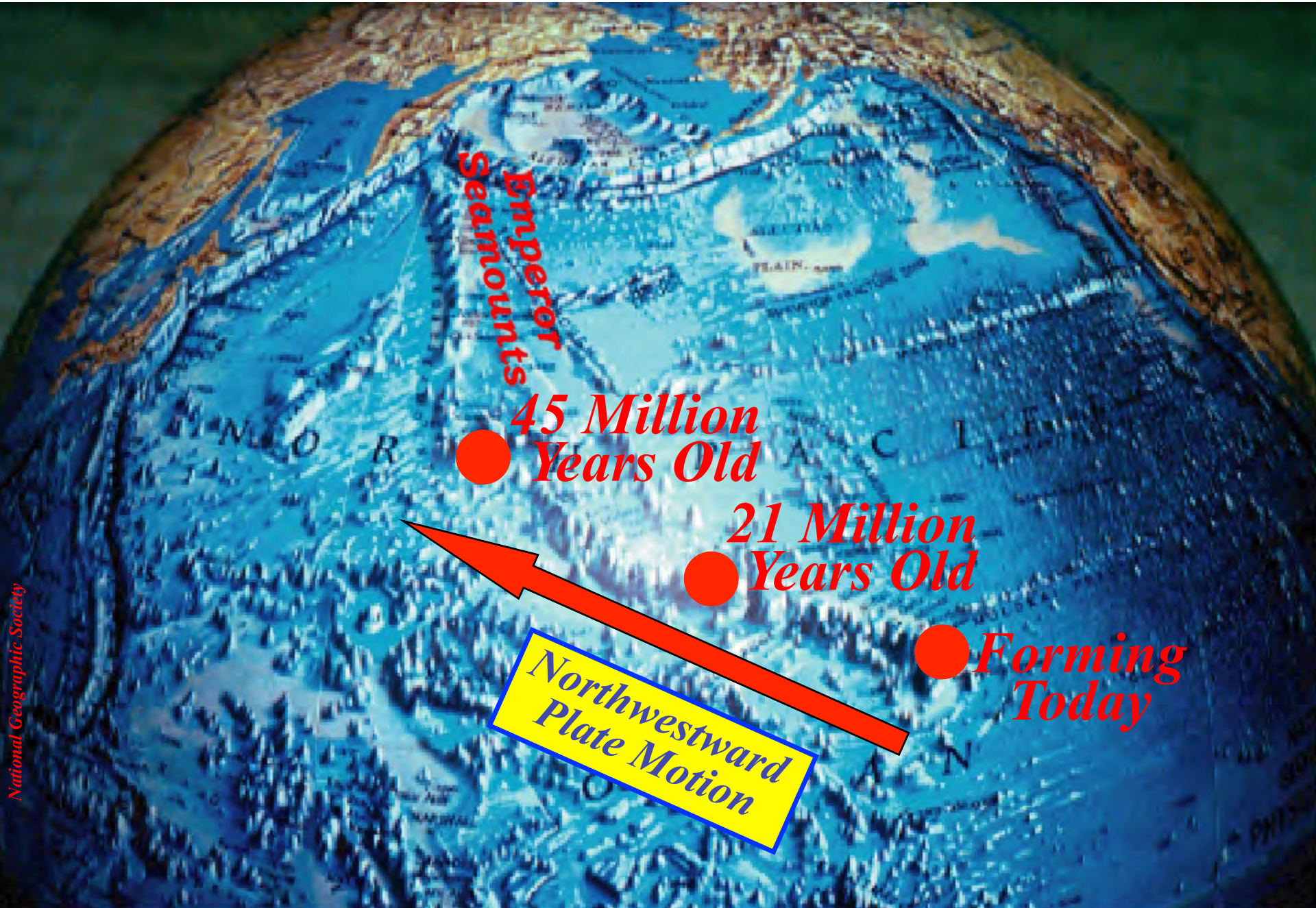
Plate Tectonics

Most volcanoes and earthquakes occur along plate boundaries.



Modified from USGS Graphics and Lillie, 2005, "Parks and Plates"

Hawai`i – Emperor Hotspot Track



Pacific Plate Riding Over Hawaiian Hotspot

Hawai`i Volcanoes National Park, Hawai`i

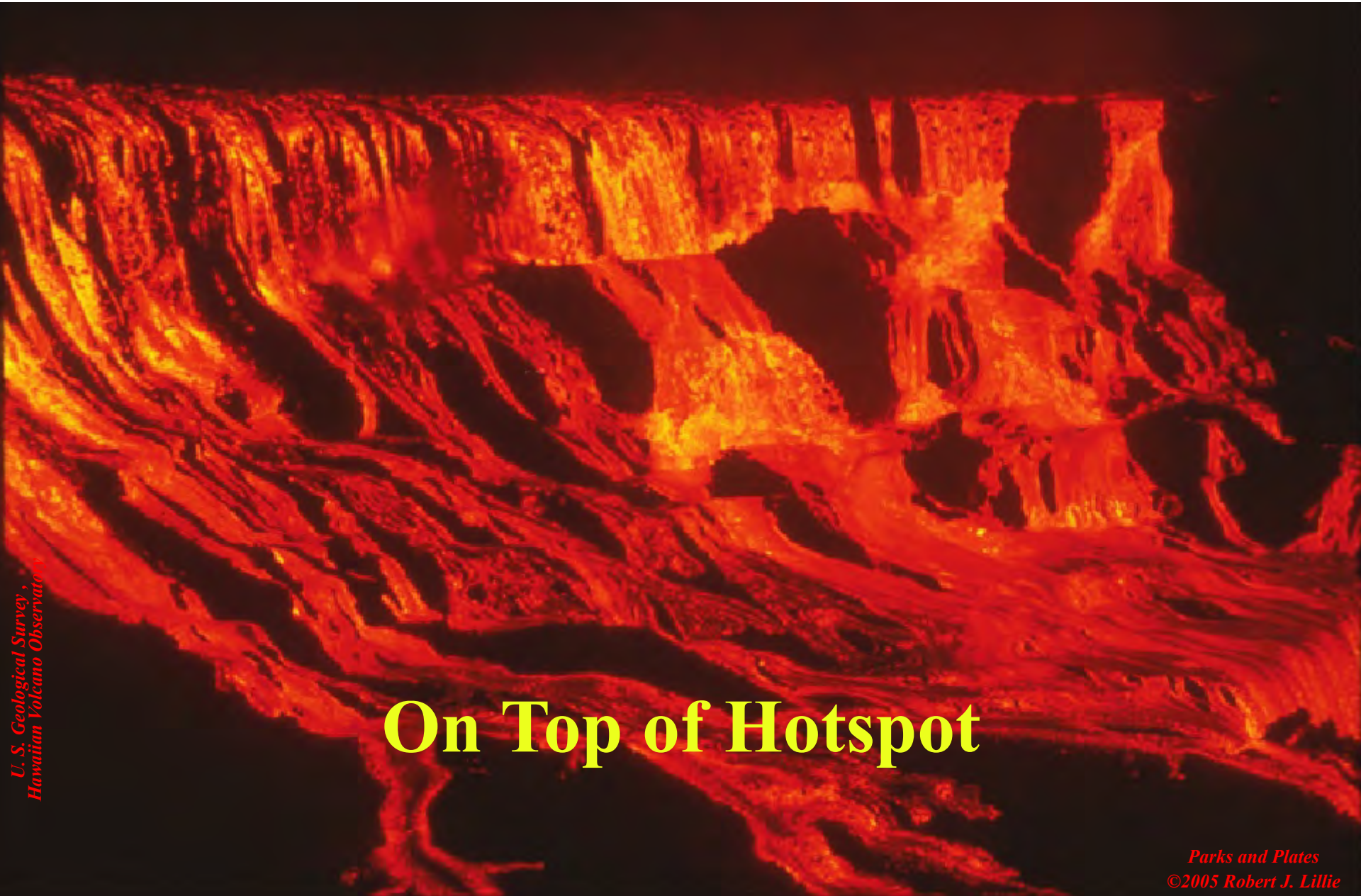
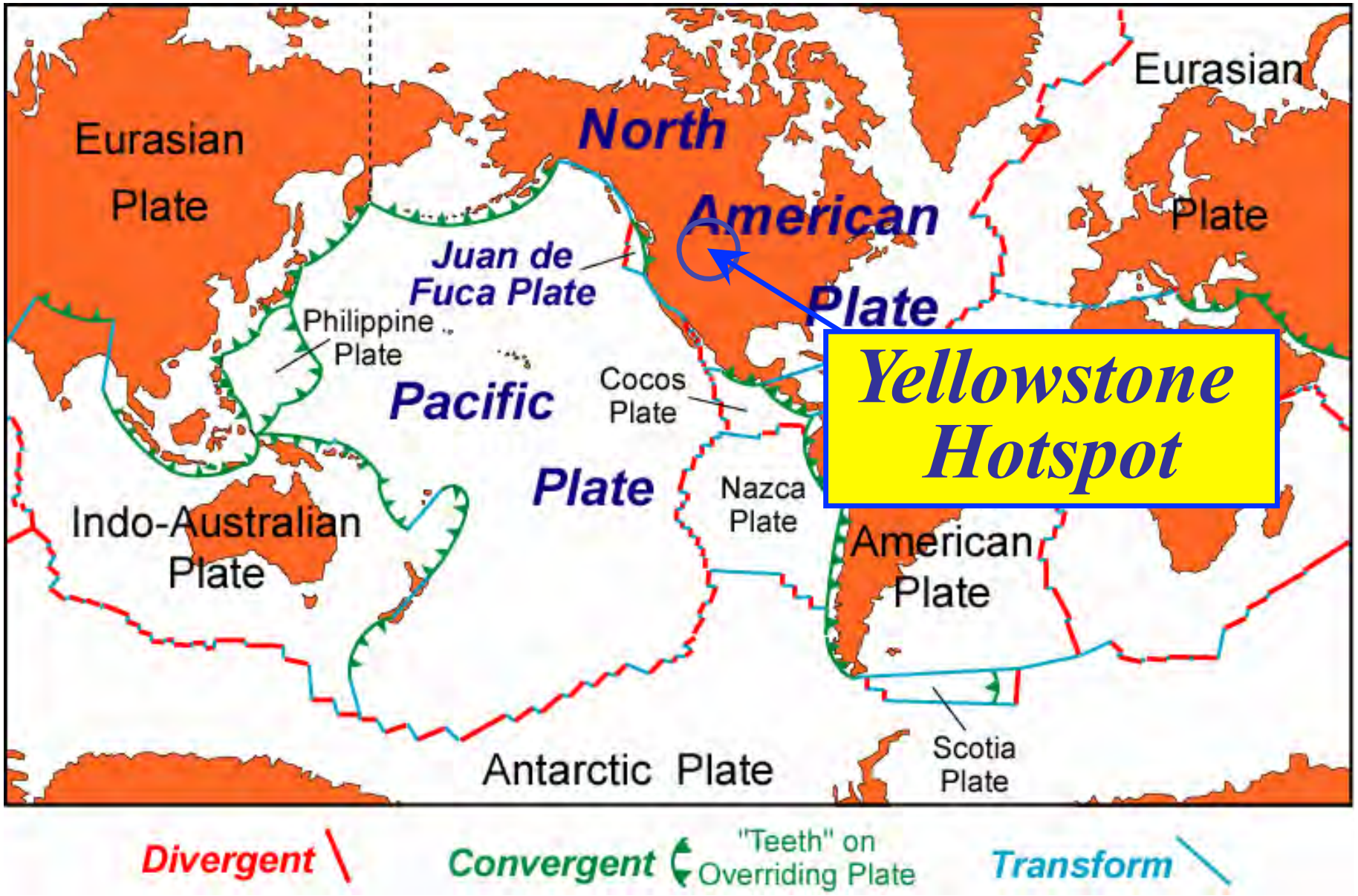
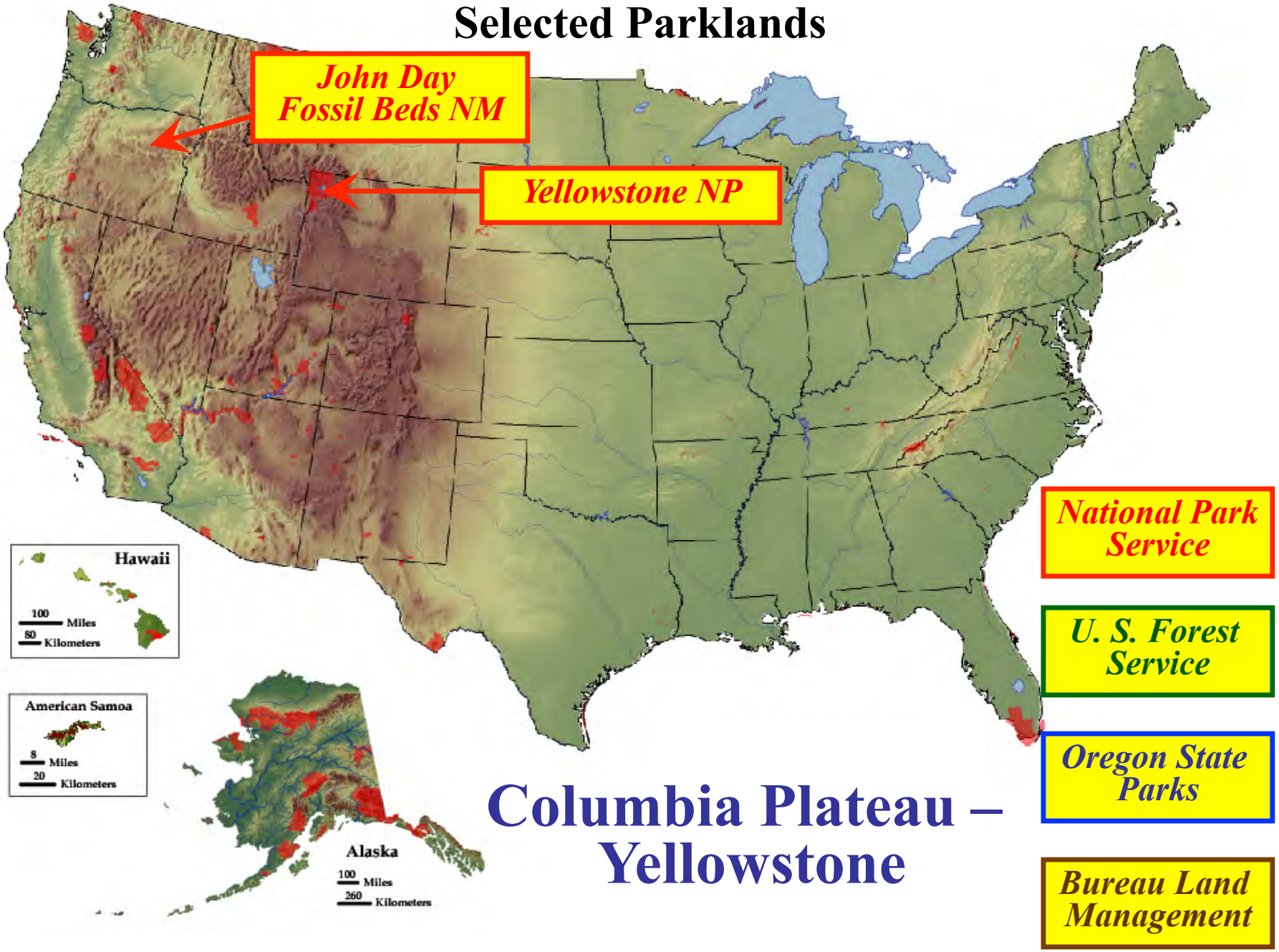


Plate Boundaries

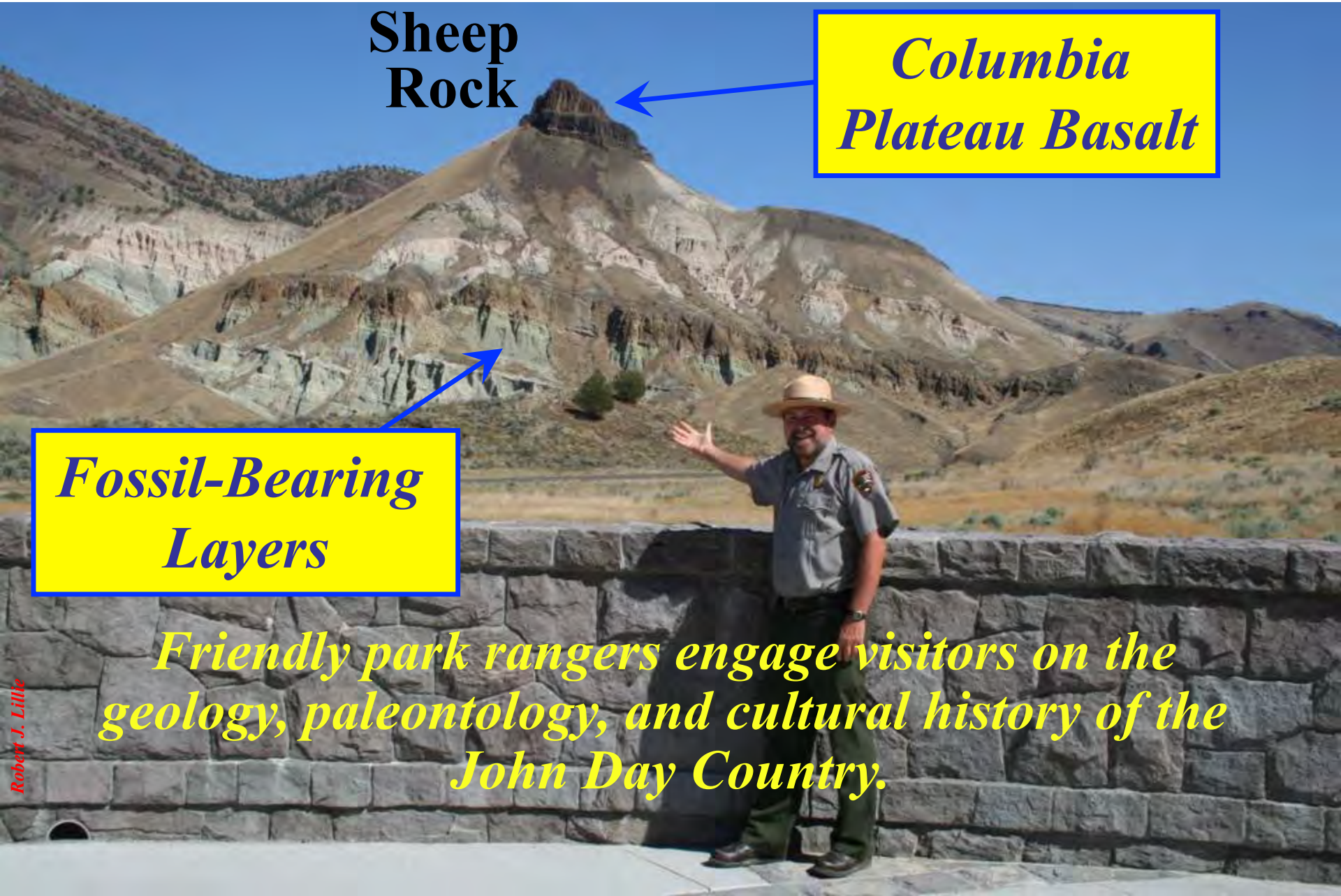


Selected Parklands



Columbia Plateau – Yellowstone

John Day Fossil Beds National Monument, Oregon



John Day Fossil Beds National Monument, Oregon

Columbia Plateau Basalt

Surfacing of Hotspot

Picture Gorge

Robert J. Lillie

Yellowstone National Park, Wyoming

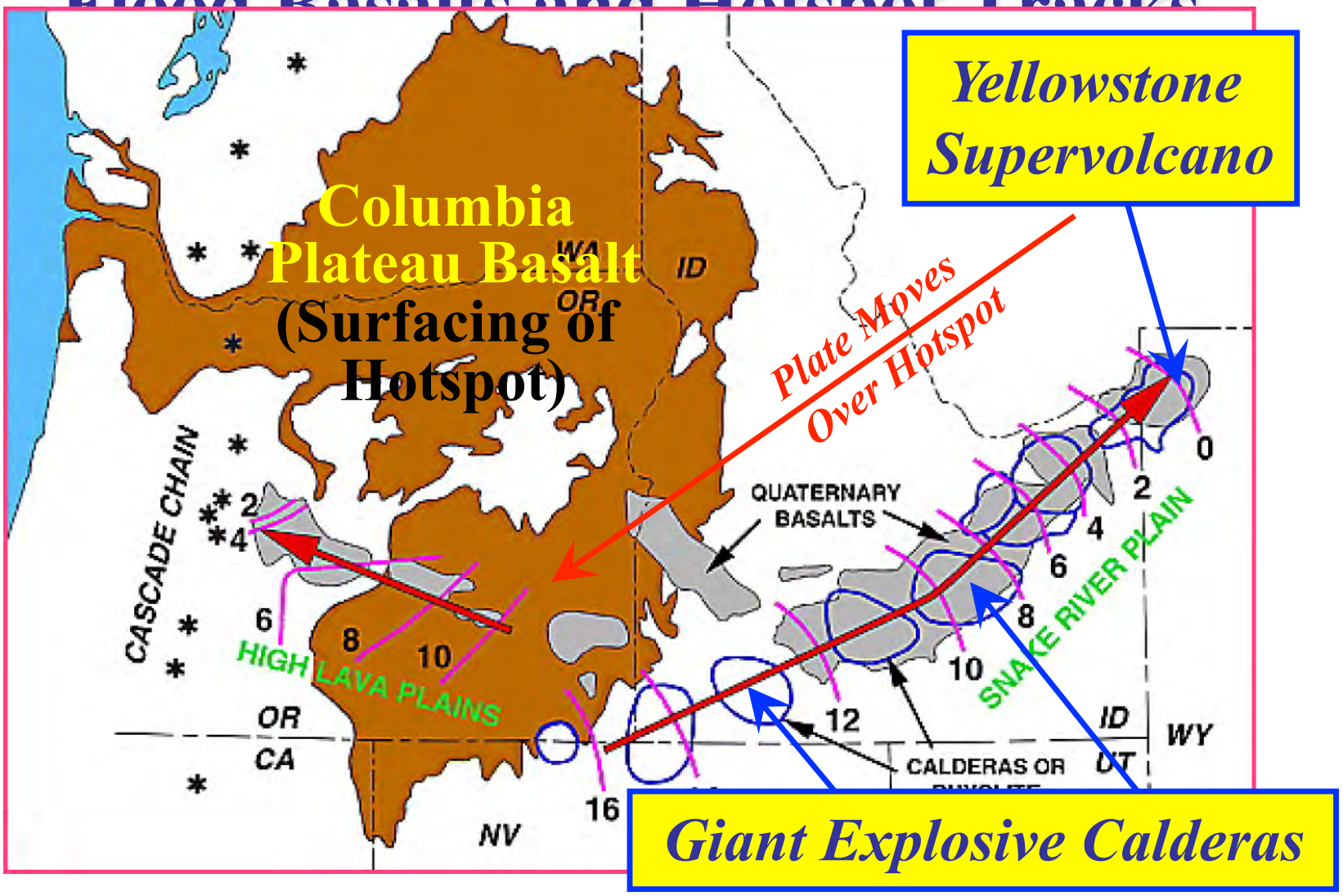
On Top of Hotspot

Robert J. Lillie

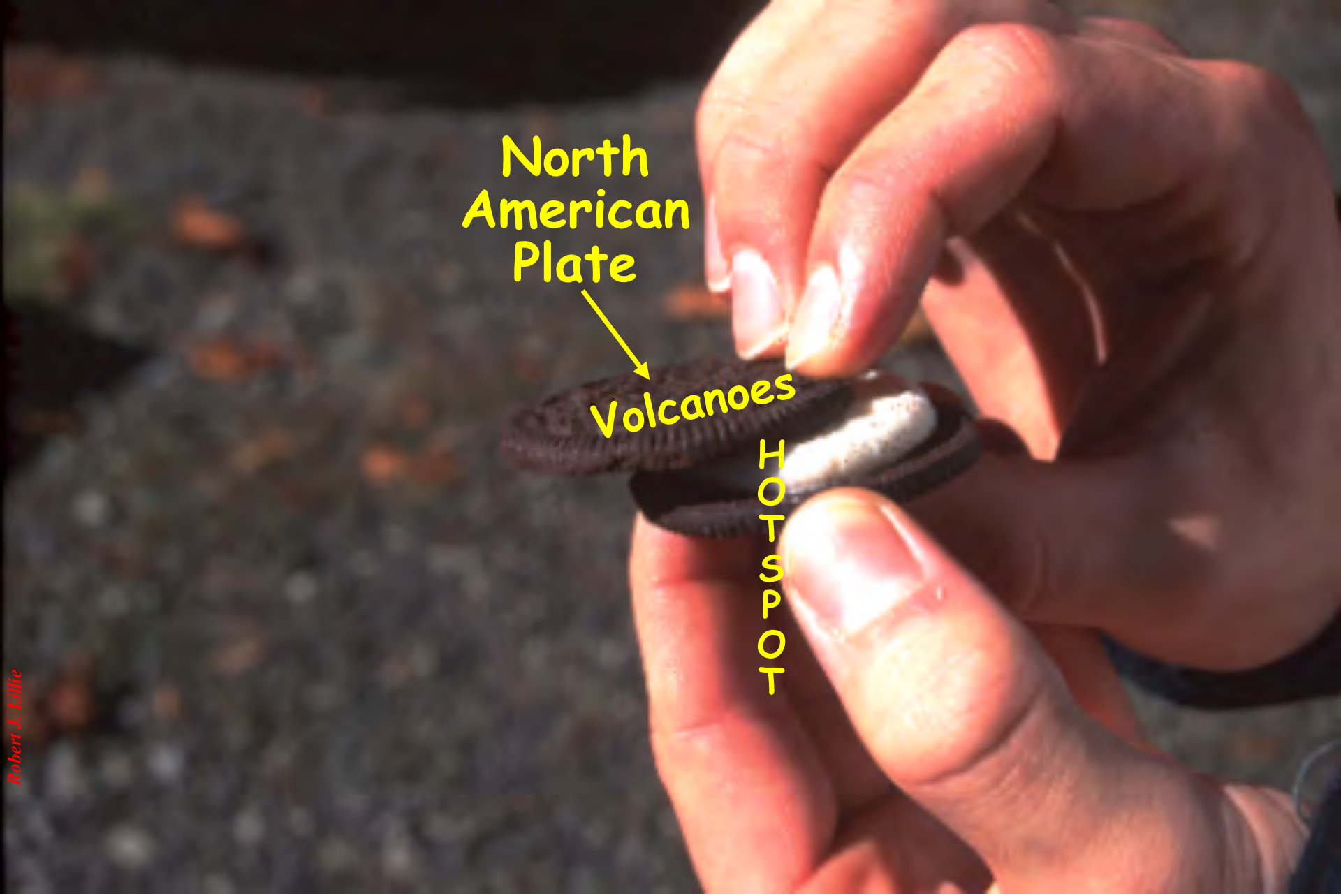
This BBC production brought great global awareness of Yellowstone as an active volcano

Numbers are age of initial lava eruptions (millions of years)

Flood Basalts and Hotspot Tracks

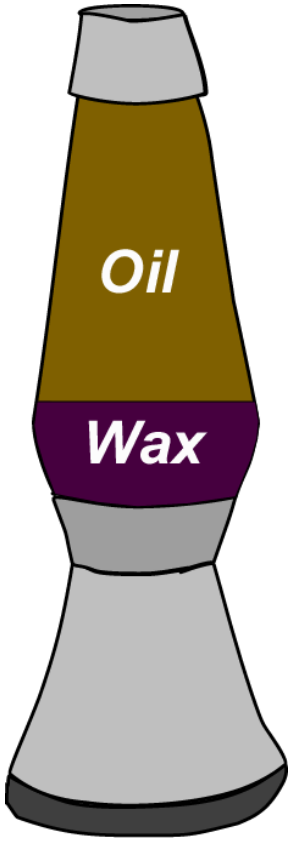


From Camp and Ross, JGR 2004



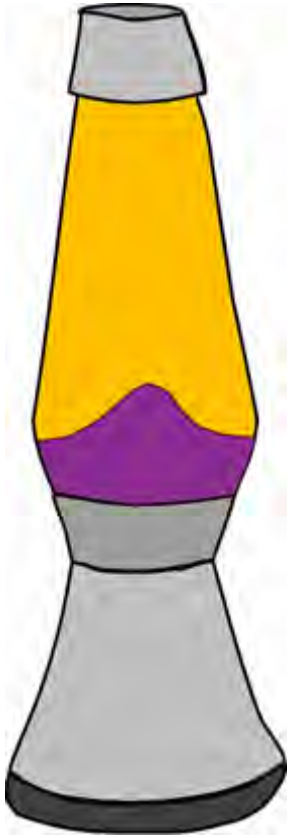
Hotspot

Lava Lamp

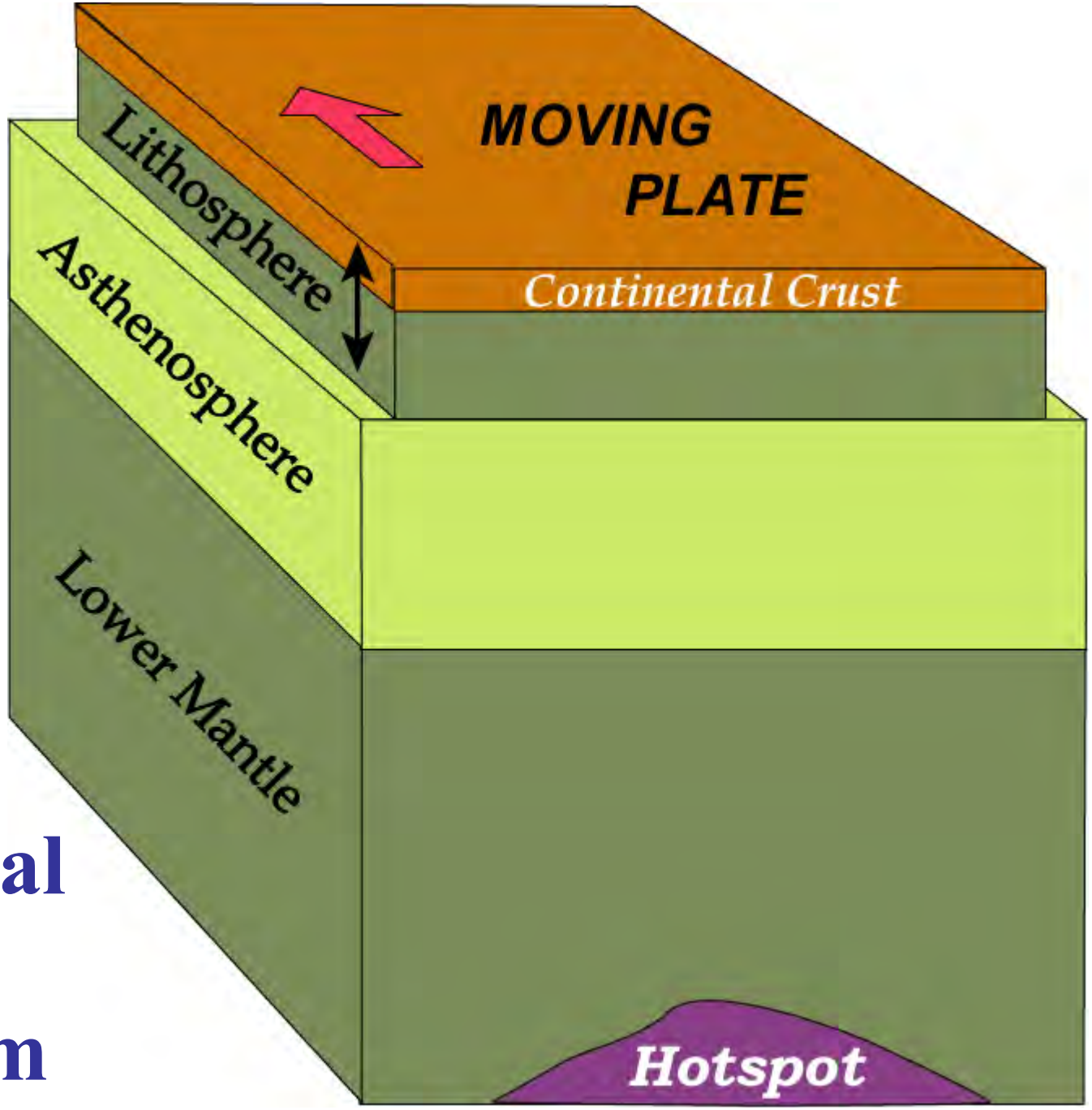


Continental Hotspot Volcanism

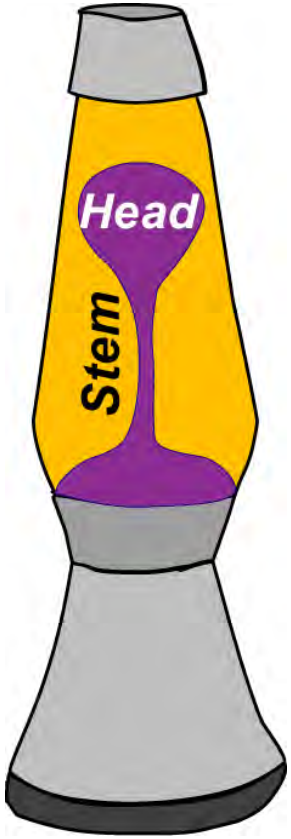
Lava Lamp



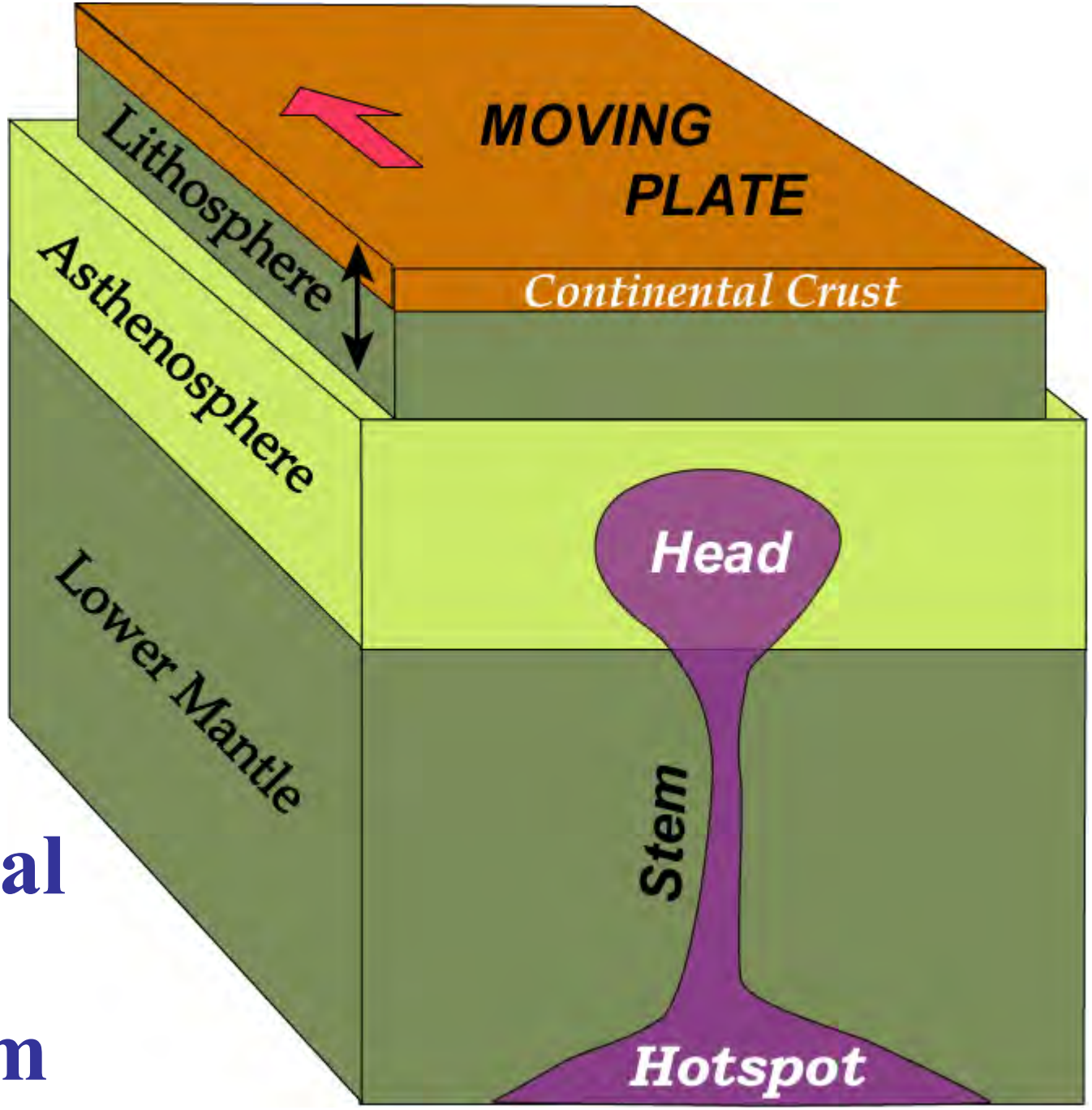
Continental Hotspot Volcanism



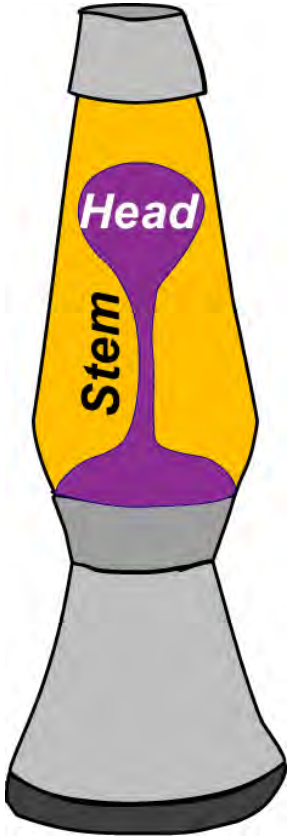
Lava Lamp



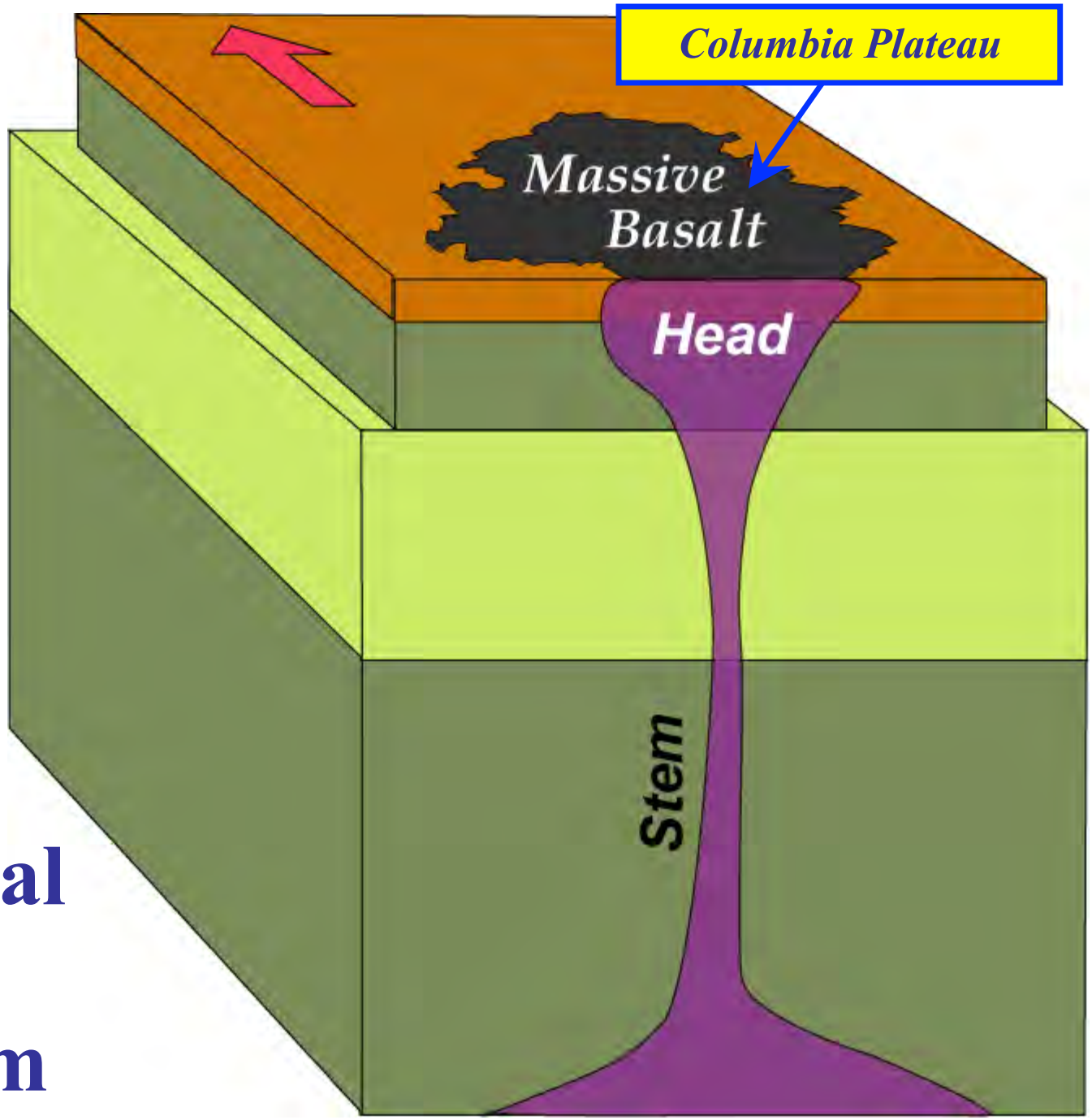
Continental Hotspot Volcanism



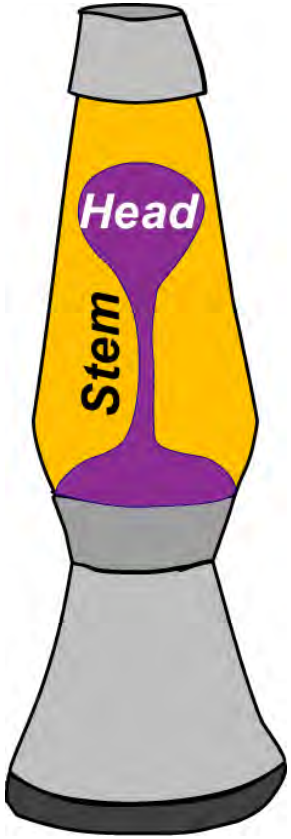
Lava Lamp



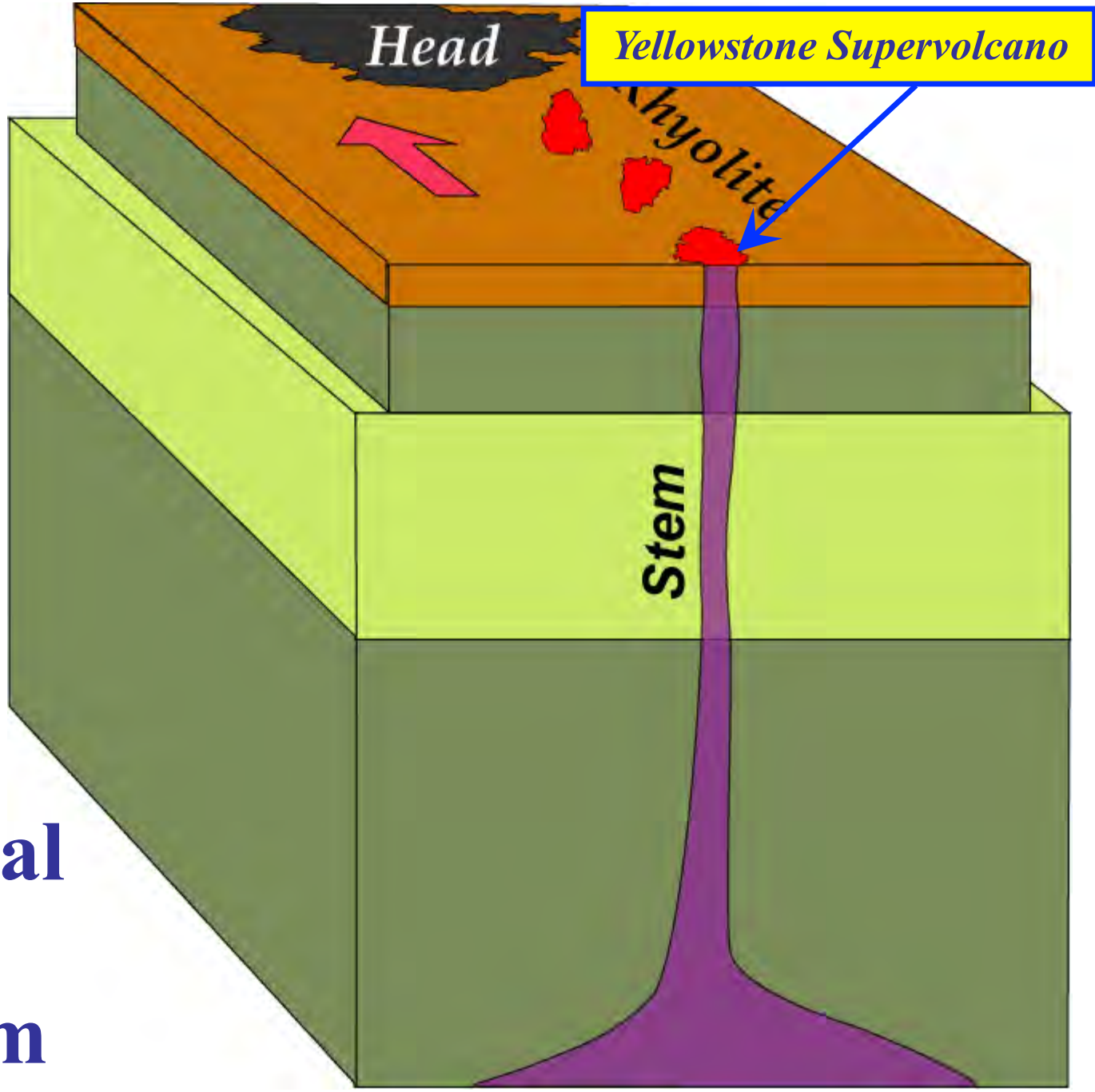
Continental Hotspot Volcanism



Lava Lamp

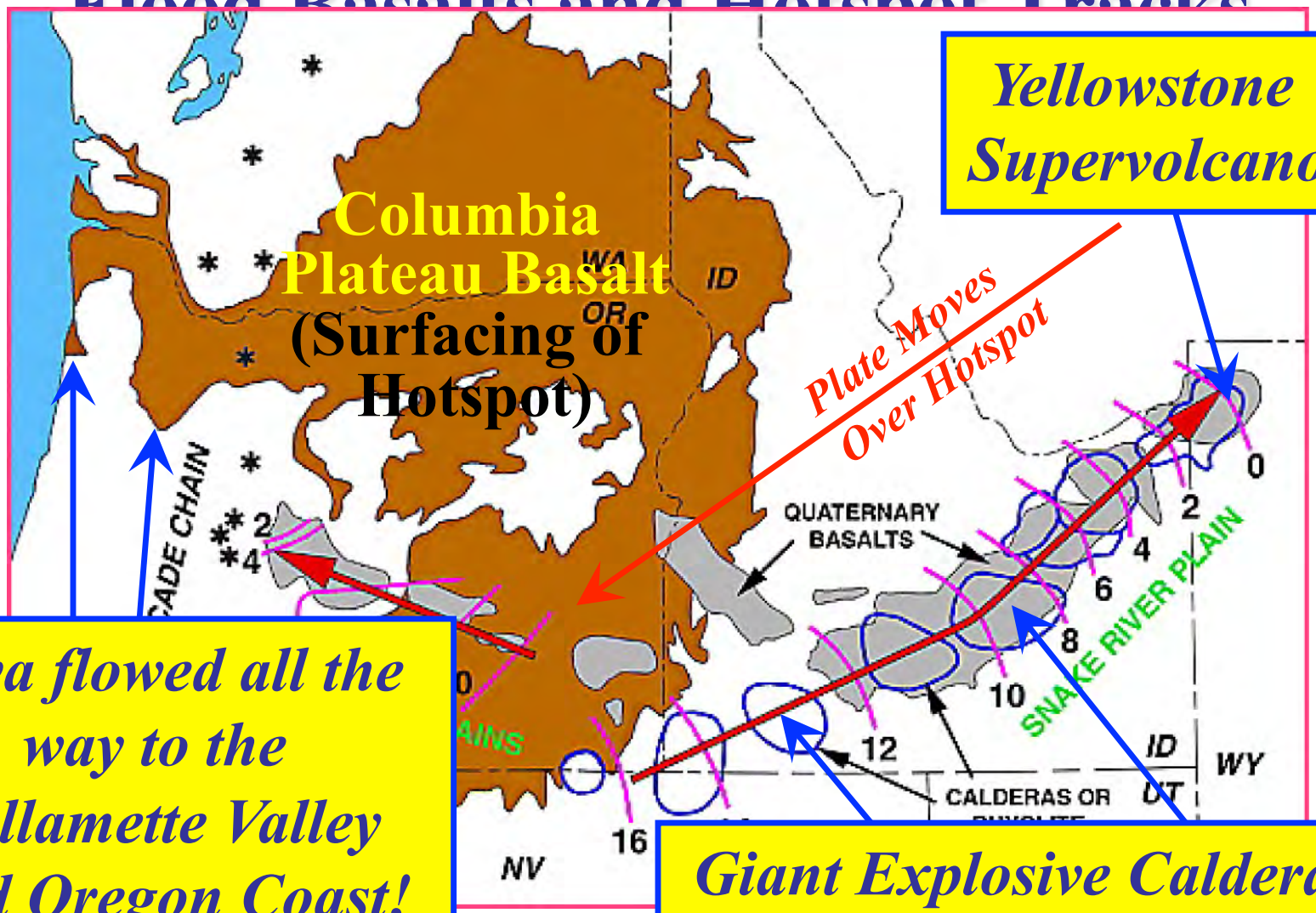


Continental Hotspot Volcanism

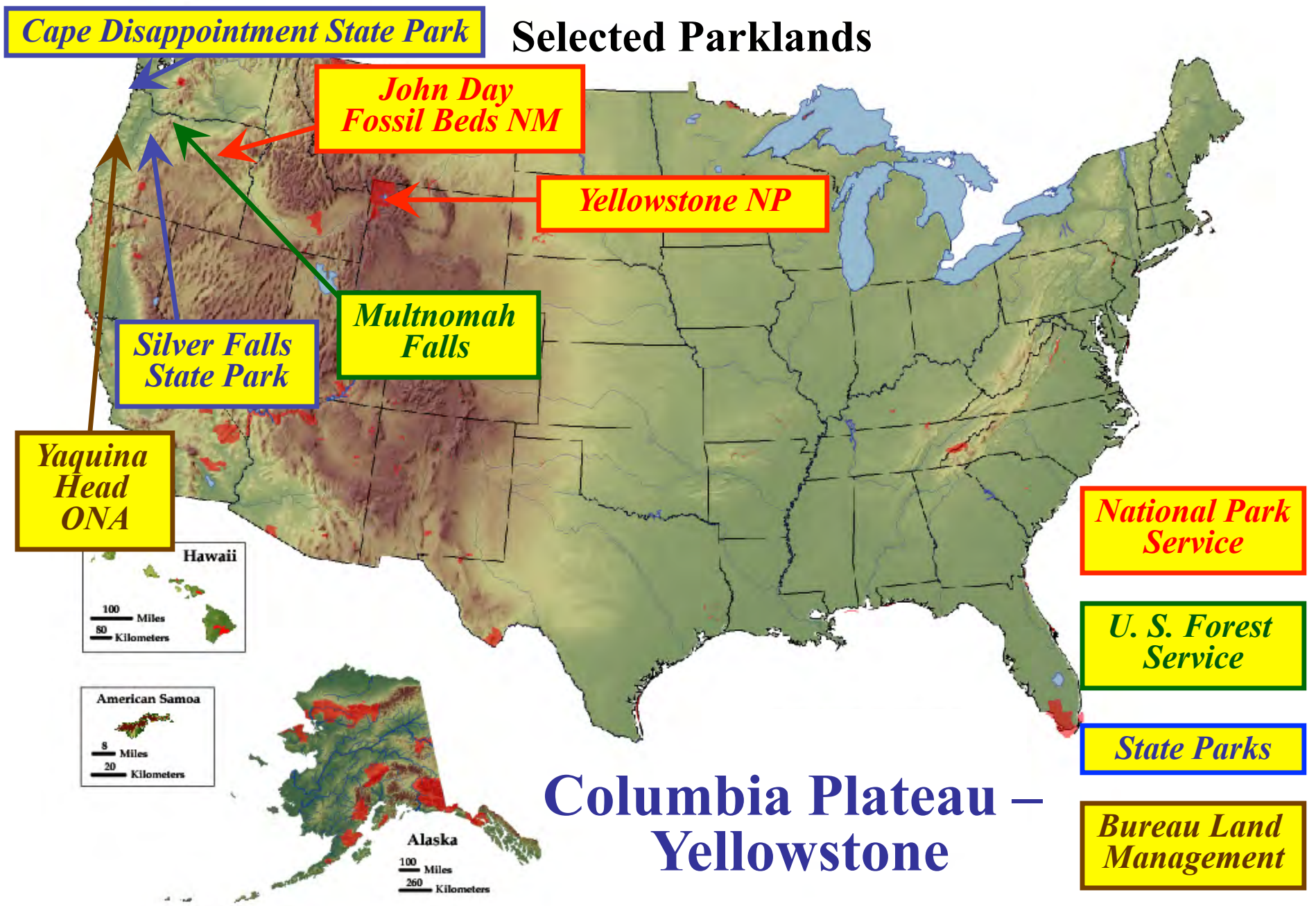


Numbers are age of initial lava eruptions (millions of years)

Flood Basalts and Hotspot Tracks



From Camp and Ross, JGR 2004


Cape Disappointment State Park
Selected Parklands
John Day Fossil Beds NM
Yellowstone NP
Multnomah Falls
Silver Falls State Park
Yaquina Head ONA
Hawaii
100 Miles
80 Kilometers
American Samoa
8 Miles
20 Kilometers
Alaska
100 Miles
260 Kilometers
National Park Service
U. S. Forest Service
State Parks
Bureau Land Management
Columbia Plateau – Yellowstone

Many of the Northwest's majestic waterfalls flow over resistant Columbia Plateau Basalt

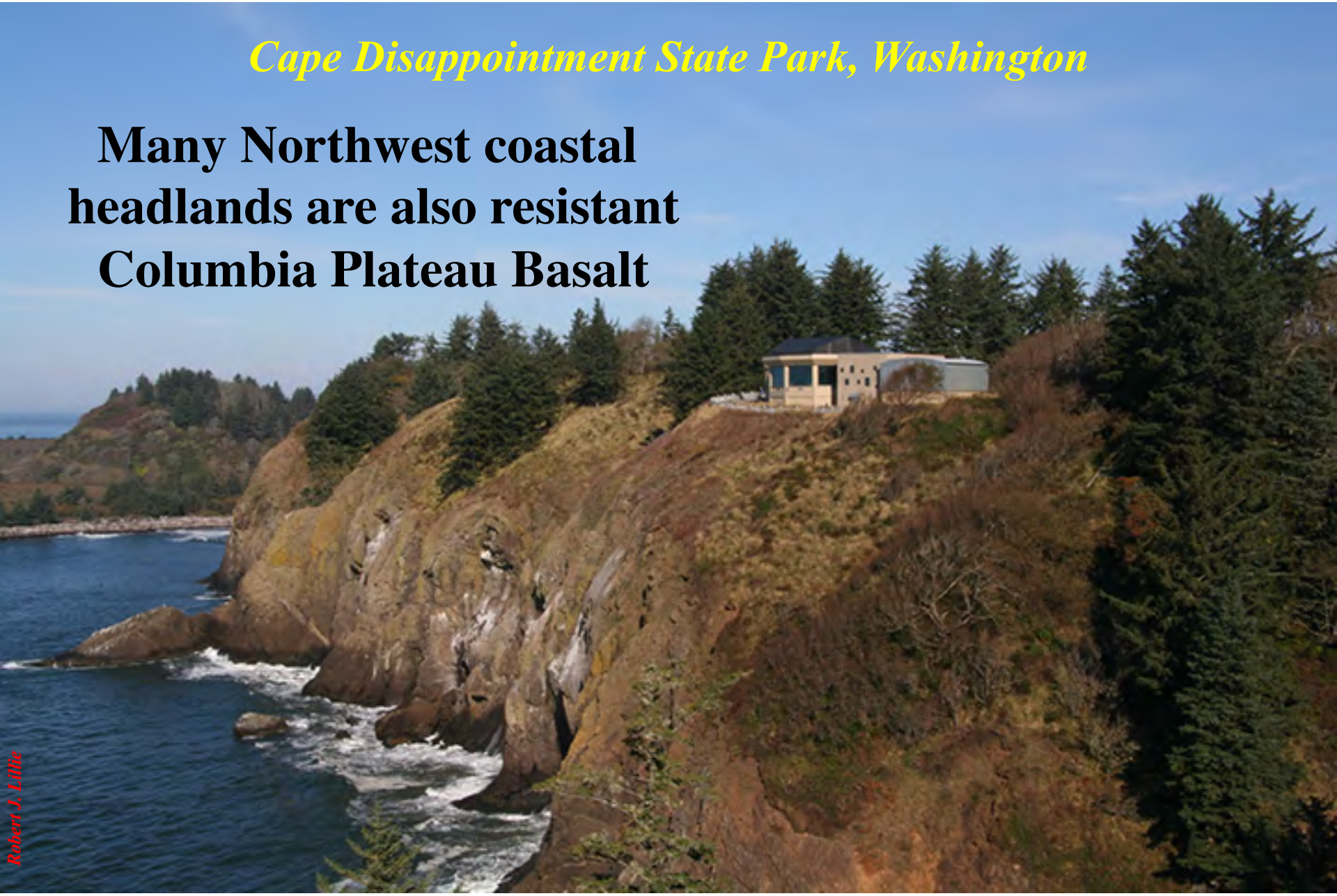
Columbia Gorge National Scenic Area, Oregon/ Washington

U. S. Forest Service

Many of the Northwest's majestic waterfalls flow over resistant Columbia Plateau Basalt

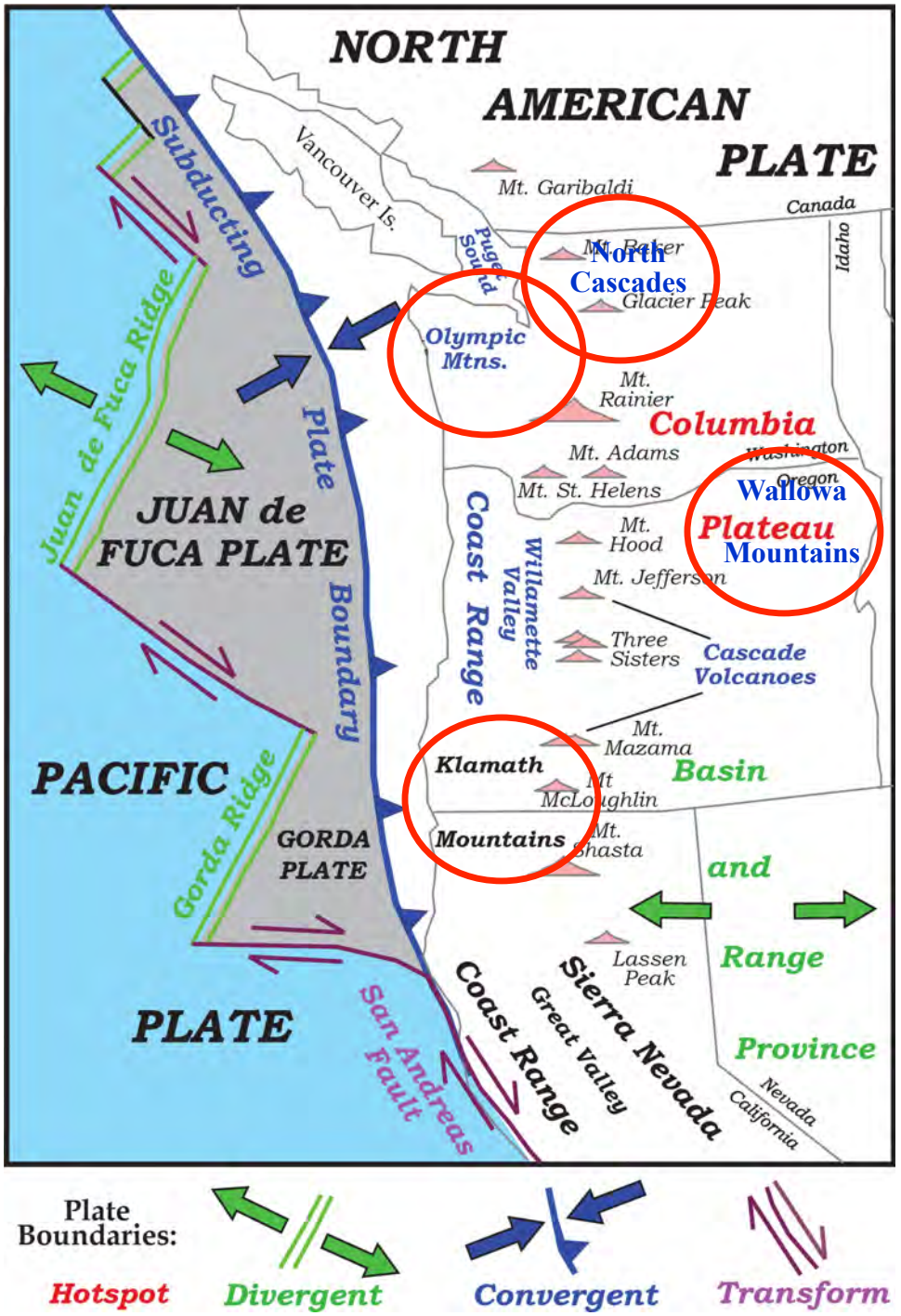
Yaquina Head Outstanding Natural Area, Oregon


Many Northwest coastal headlands are also resistant Columbia Plateau Basalt
Cape Disappointment State Park, Washington
Astoria, Oregon
Robert J. Lillie


Cape Disappointment State Park, Washington
Many Northwest coastal headlands are also resistant Columbia Plateau Basalt
Robert J. Lillie

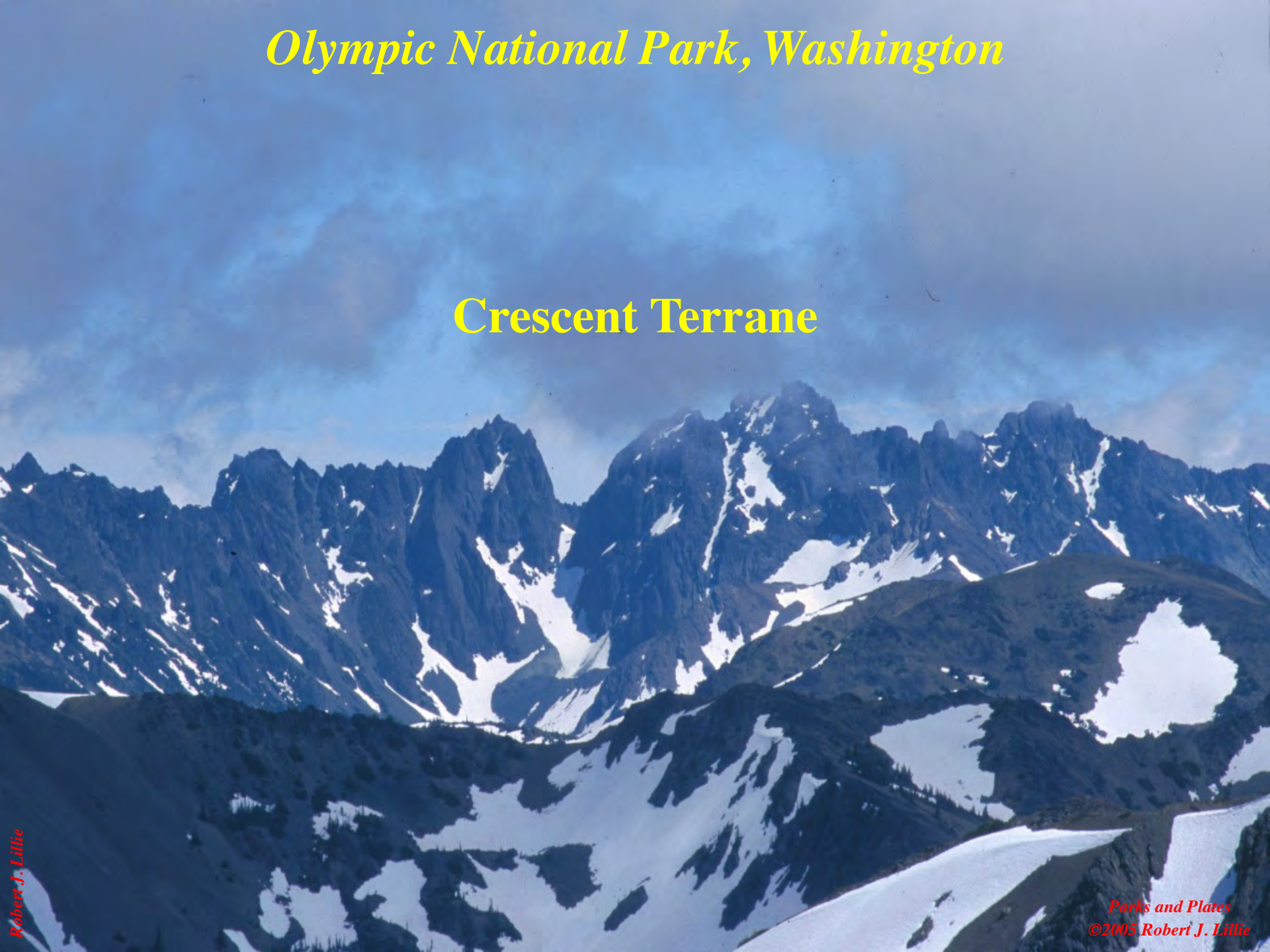
Most of the landscapes of the Pacific Northwest are due to ongoing processes at plate boundaries and hotspots.

What about these older mountain ranges?

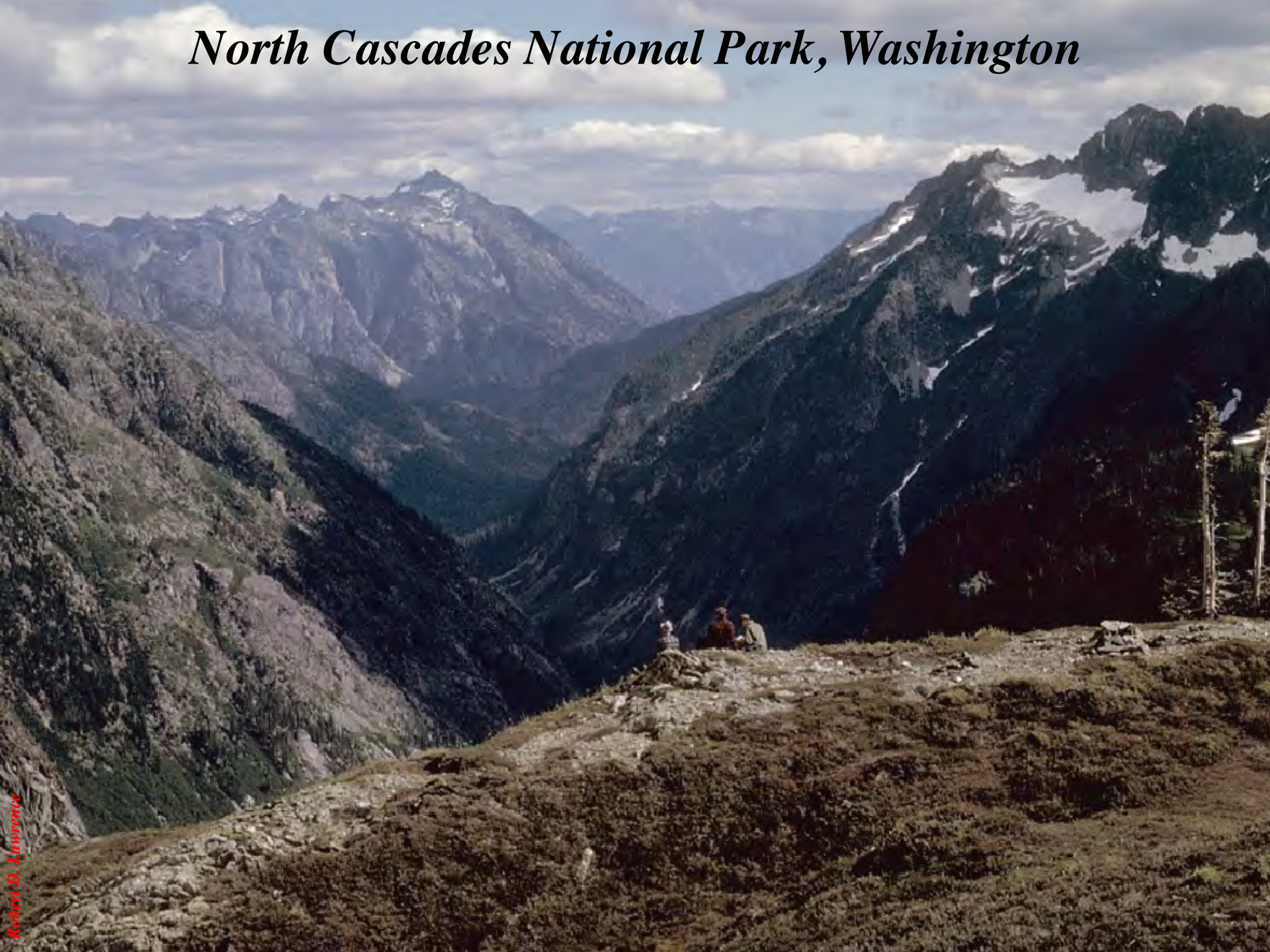


Olympic National Park, Washington

Crescent Terrane



North Cascades National Park, Washington



Robert D. Lawrence

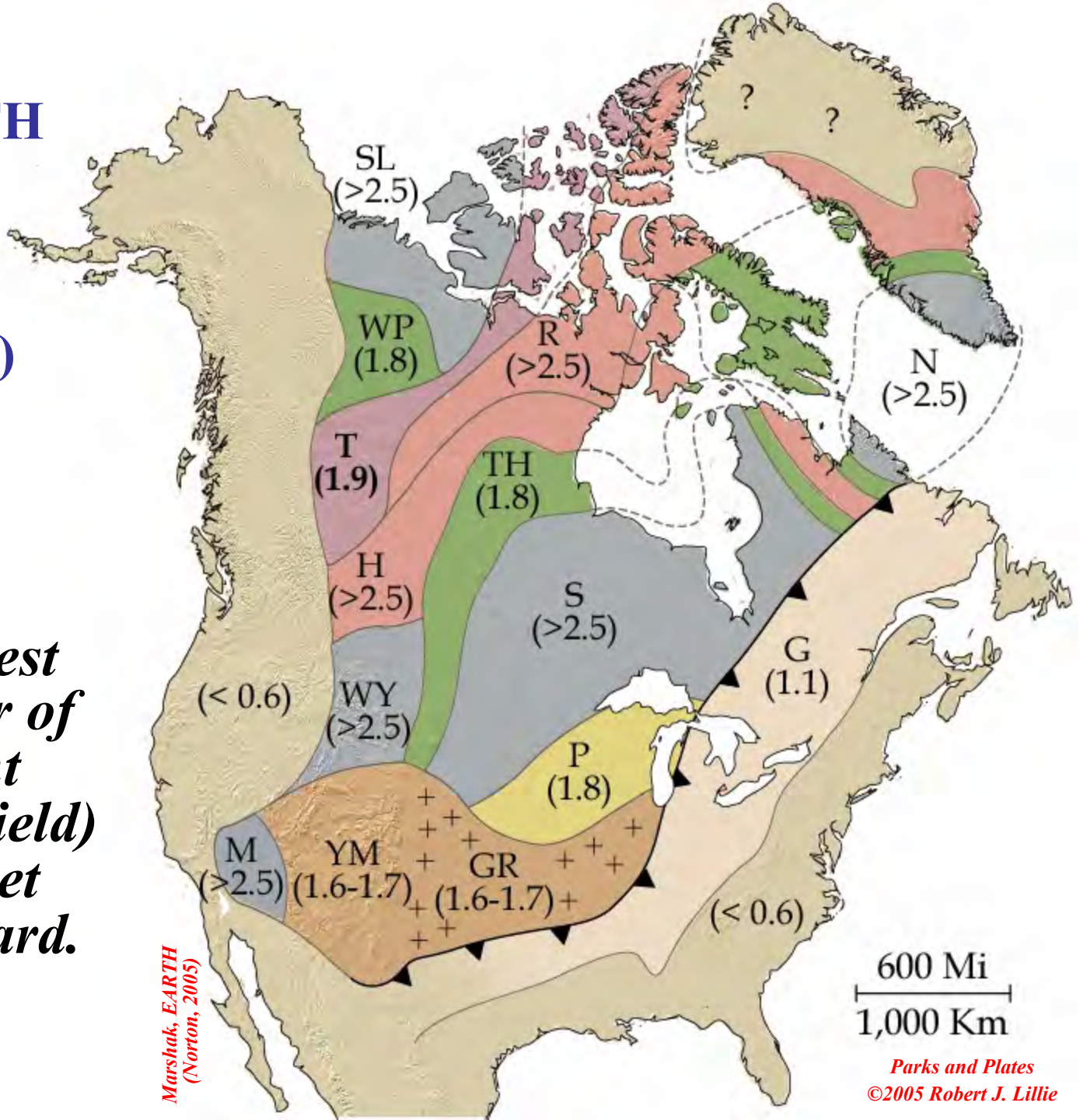
Iwetemlaykin State Heritage Site, Oregon


Oregon Caves National Monument,
Oregon
Klamath Mountains
National Park Service
http://www.nps.gov/common/uploads/photogallery/pwr/park/orca/F2BC0D25-155D-4519-3ED261B291524FF7/F2BC0D25-155D-4519-3ED261B291524FF7.JPG

AGE OF NORTH AMERICAN BASEMENT ROCKS (Billions Years)

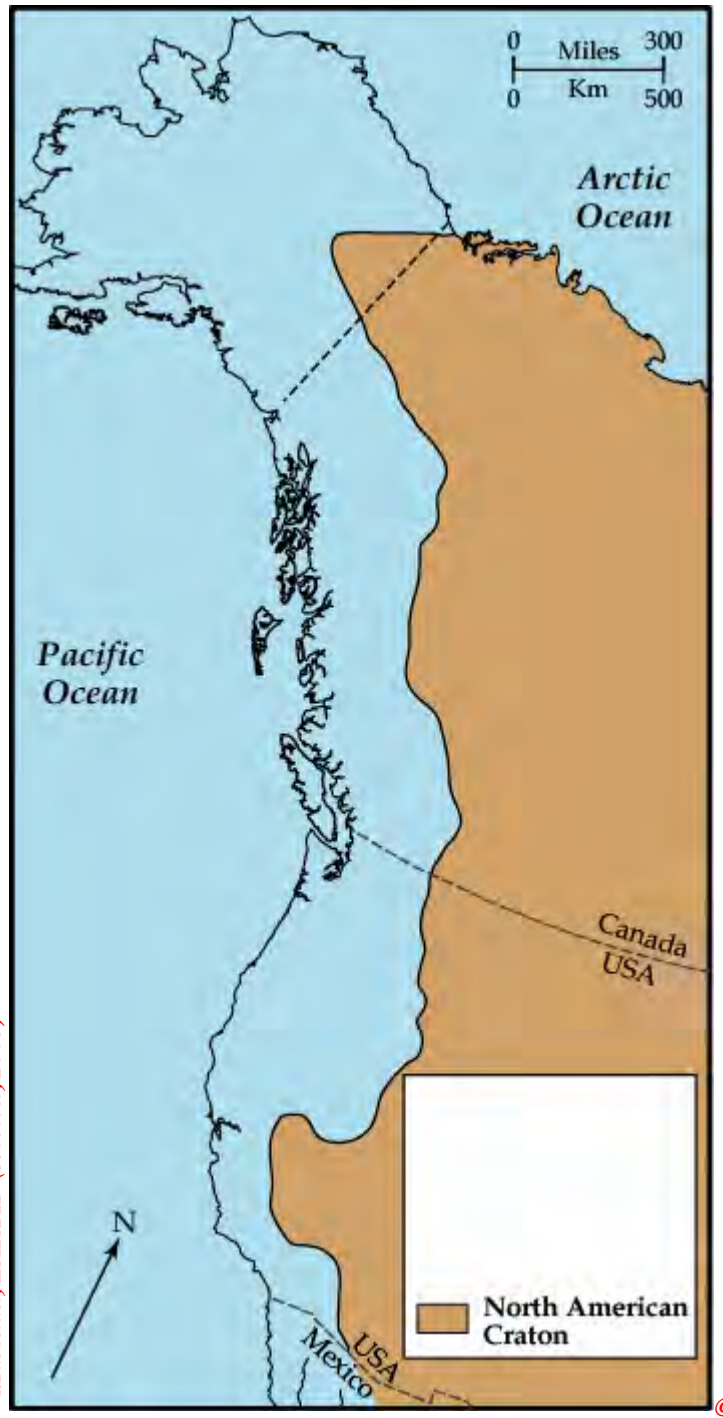
What's the Pattern?

Rocks are oldest near the center of the continent (continental shield) and tend to get younger outward.



Accreted Terranes

The CRATON is the old nucleus of the North American Continent.

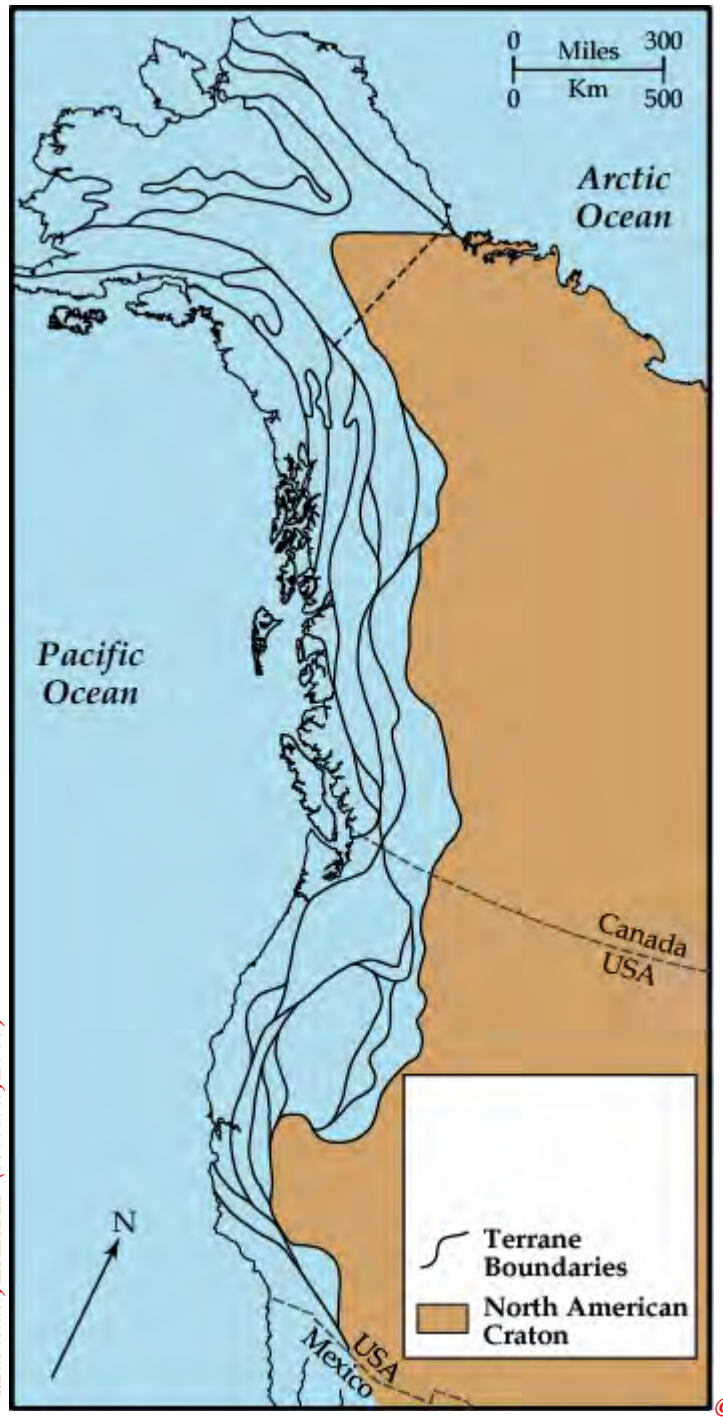


Marshak, EARTH (Norton, 2005)

Parks and Plates

Accreted Terranes

Most of the western U.S. was added to the continent in the past 200 million years or so.

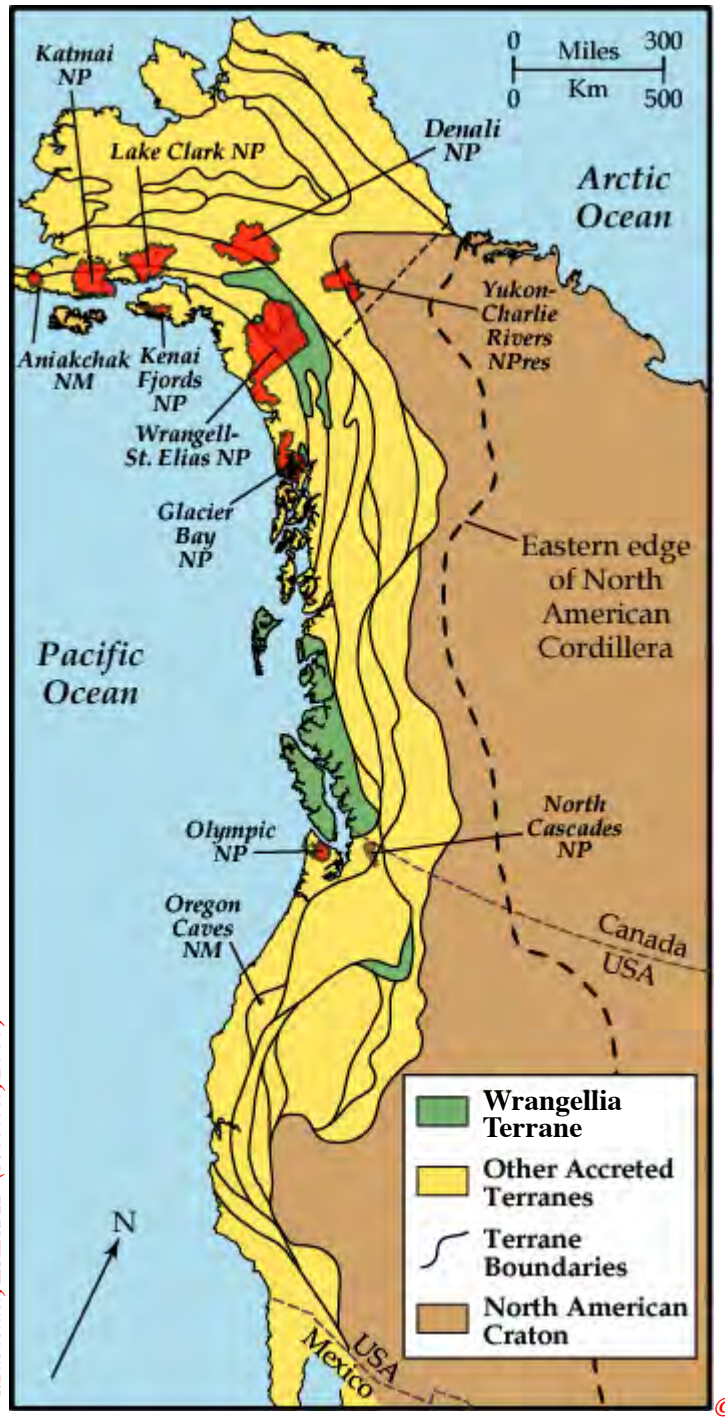


Marshak, EARTH (Norton, 2005)

Accreted Terranes

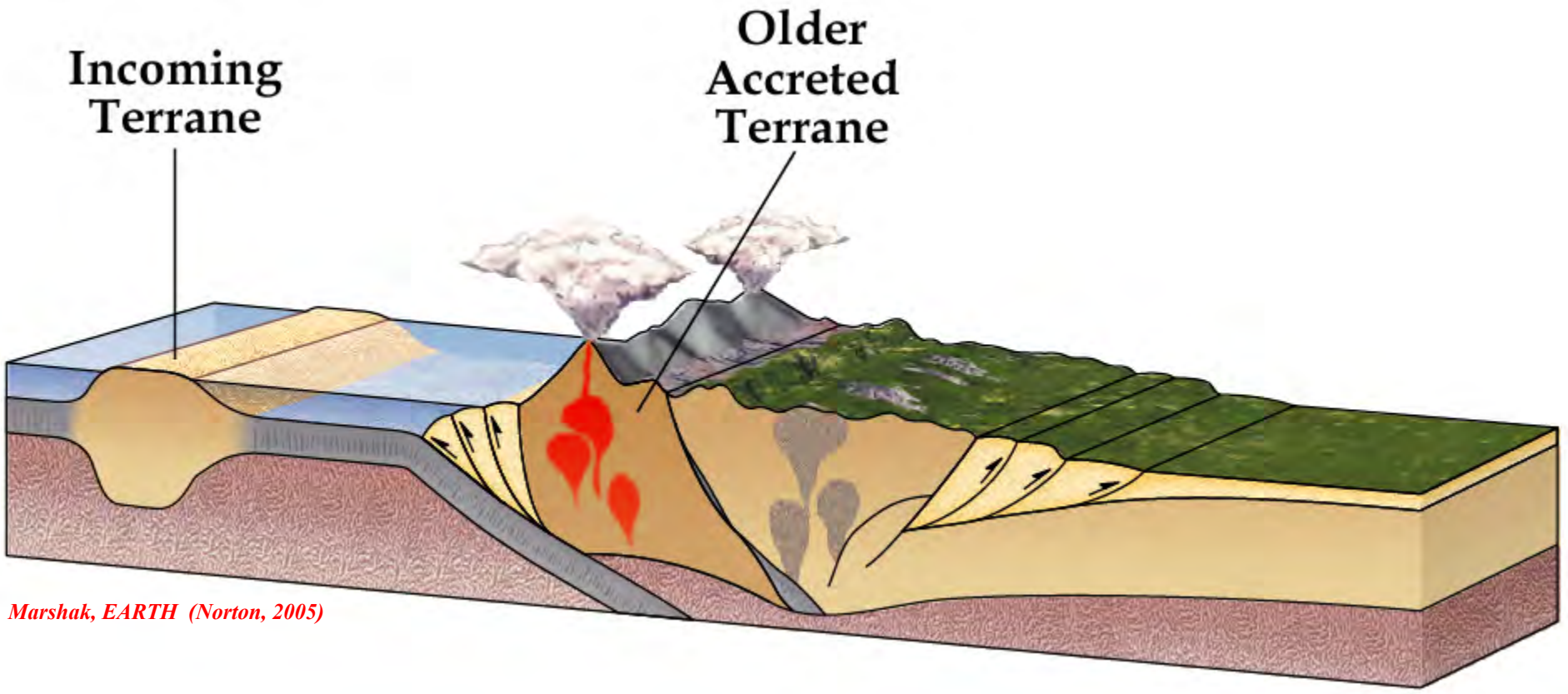
Olympic National Park, North Cascades National Park, and Oregon Caves National Monument, and many other national park sites are on accreted terranes.

NATIONAL PARKLANDS



Terrane Accretion

A <u>TERRANE</u> consists of crust that is too thick and buoyant to subduct. The continent grows outward as terranes come crashing in.



Marshak, EARTH (Norton, 2005)


Safeway Terrane Accretion ☺
Forth Terrane
Third Terrane
Second Terrane
Ocean Plate
First Terrane
North American Plate
Robert J. Lillie

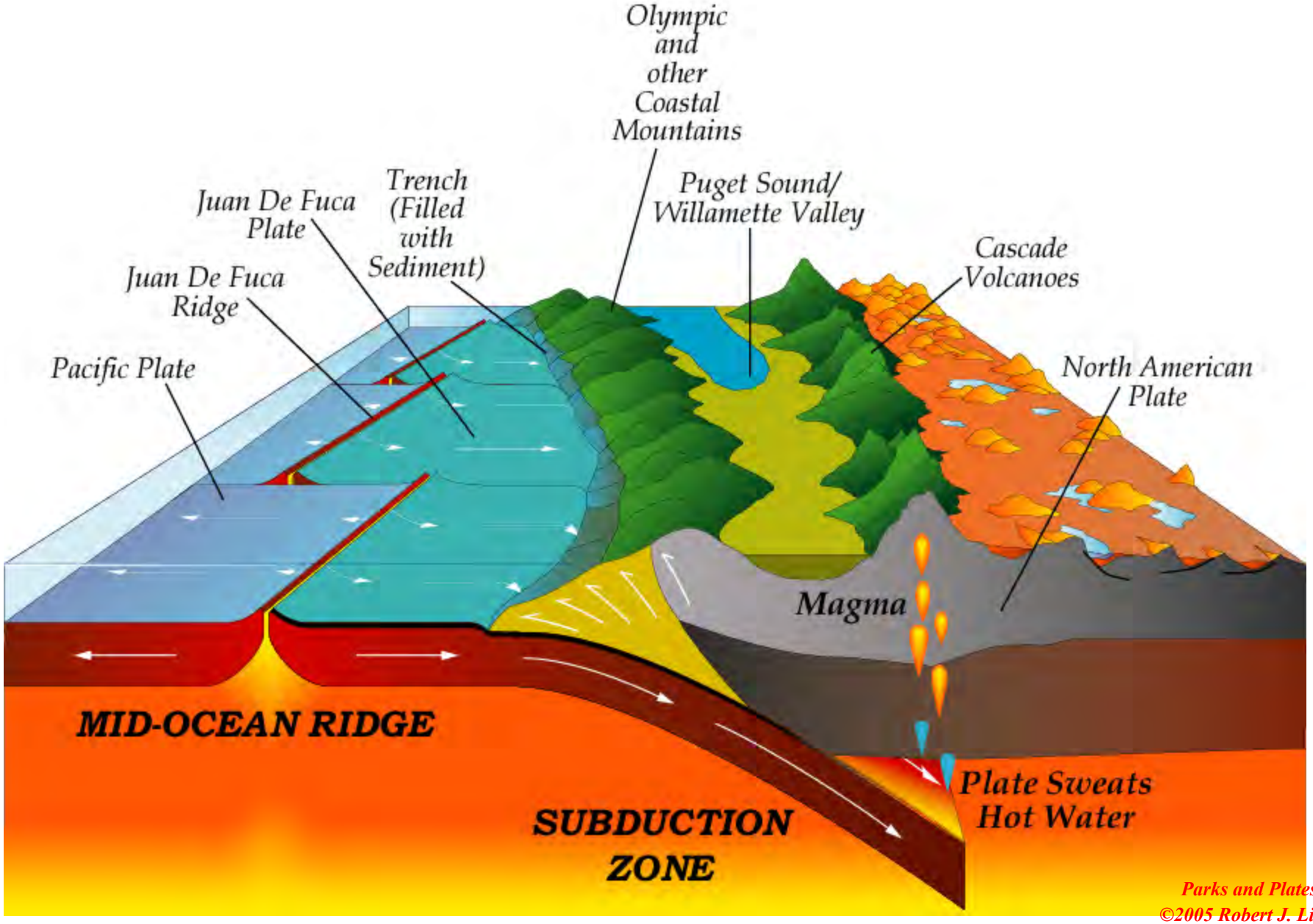

Second Terrane
First Terrane
Double Stuf
OREO
Chocolate Sandwich Cookies
Diet
UP
7
Ocean Plate
Robert J. Lillie


Double Stuf
OREO
Chocolate Sandwich Cookies
Diet
UP
Ocean Plate
Robert J. Lillie


Third Terrane
4 Giant Rolls!
=10 REGULAR ROLLS
Charmin
BATHROOM TISSUE/PAPEL HIGIENICO
Charmin
4 Giant Rolls
OREO
Ocean Plate
Robert J. Lillie


Ocean Plate
Forth Terrane
Third Terrane
Second Terrane
First Terrane
North American Plate
Robert J. Lillie

The Cascadia Subduction Zone is just the latest episode of the Pacific Northwest building outward by Terrane Accretion.

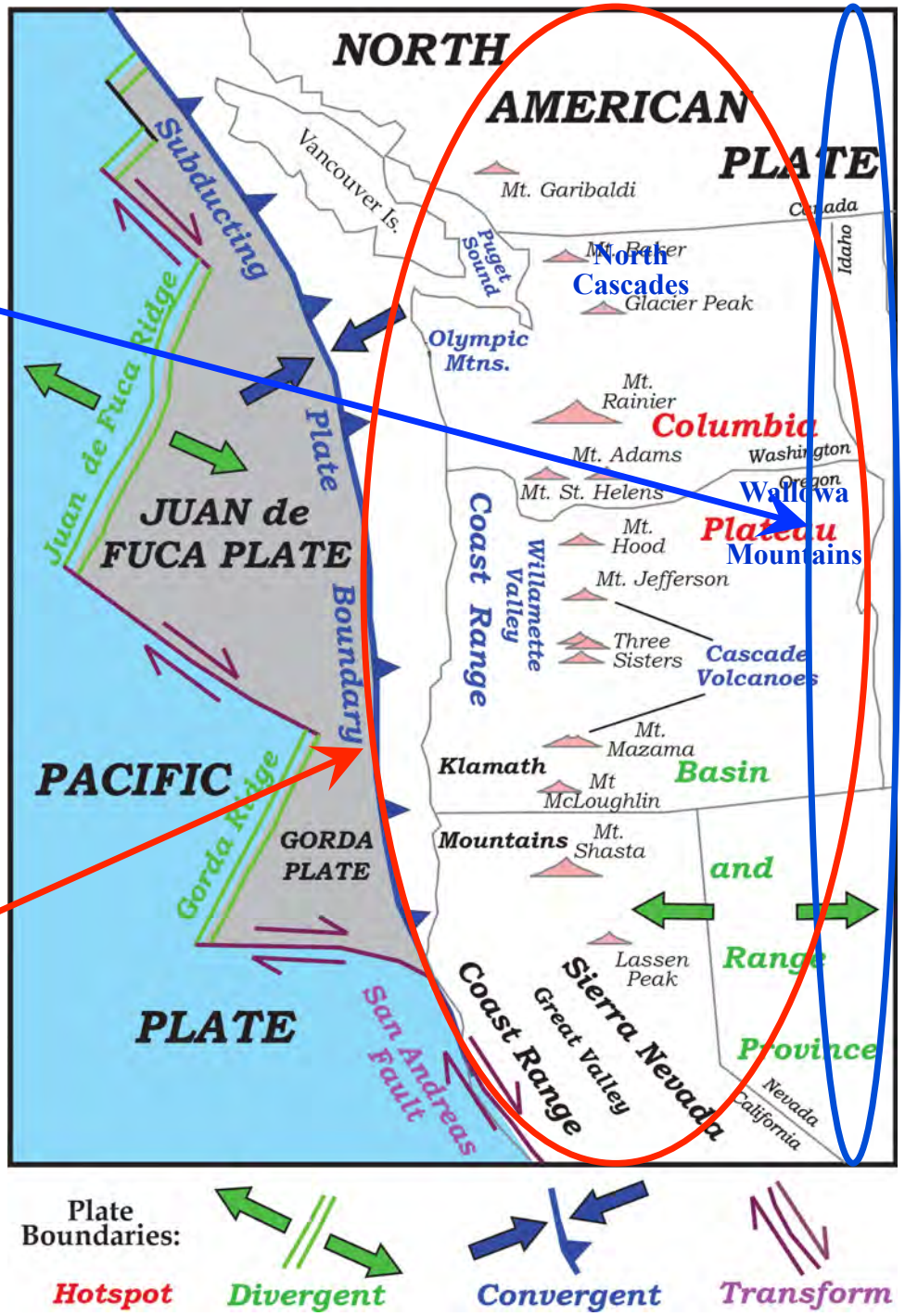


Robert J. Lillie
Bernard Garcia

Coastline 200 Million Years Ago

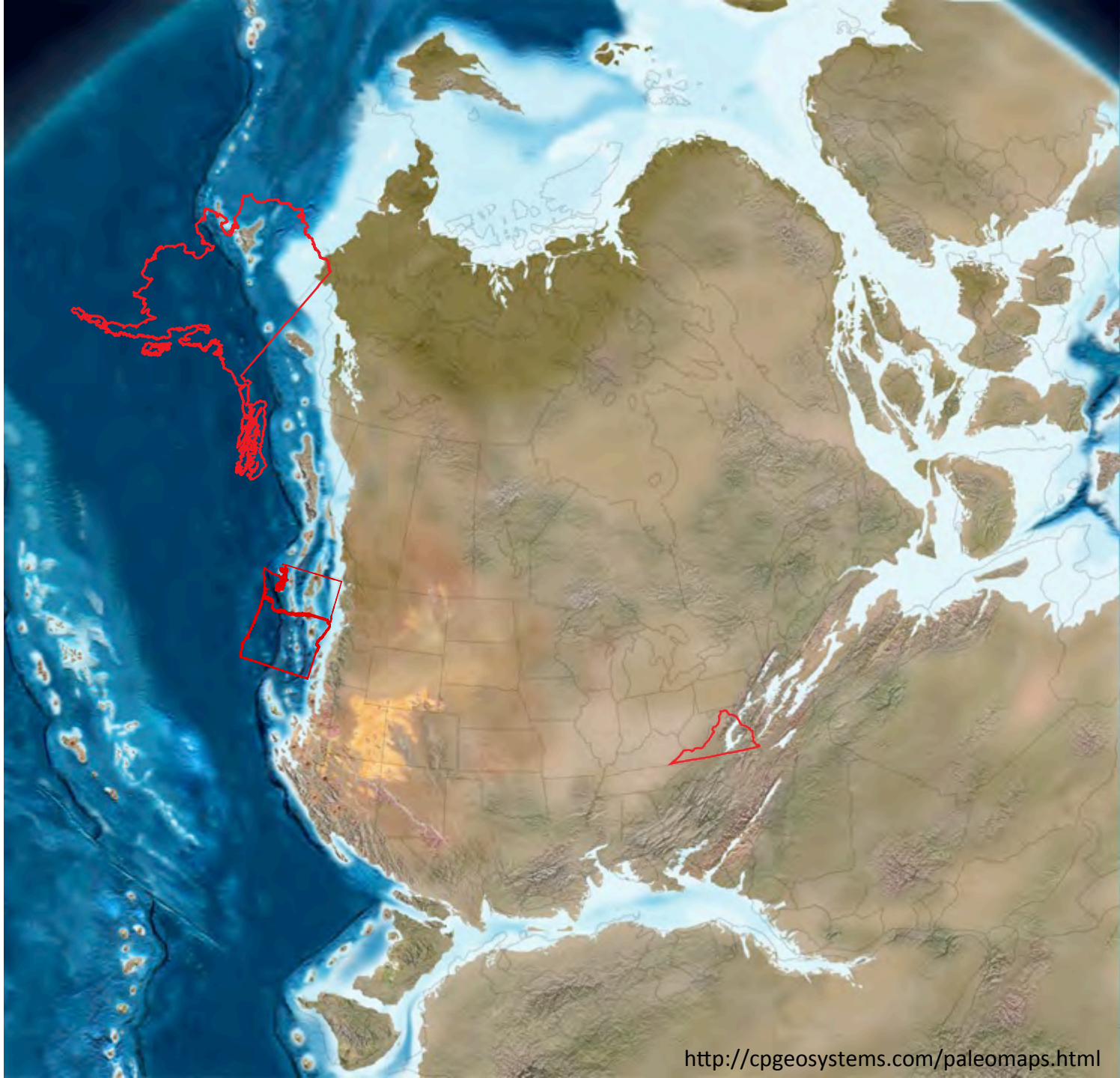
Most of Oregon and Washington has been added to the edge of the continent in the past 200 million years

Material added since then by Subduction and Terrane Accretion



Jurassic

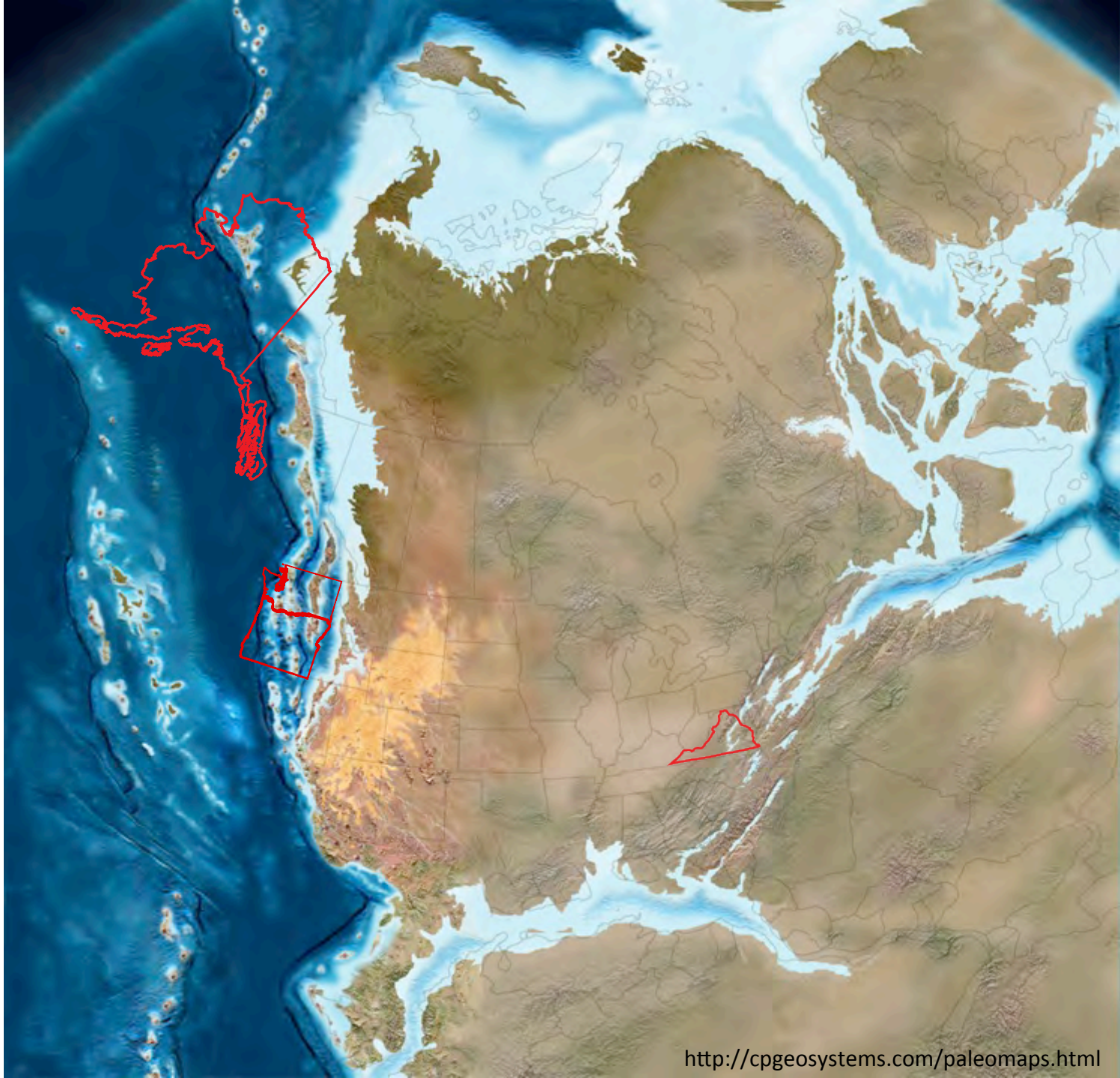
195
Million Years Ago



Ron Blakey
Northern Arizona University

http://cpgeosystems.com/paleomaps.html

Jurassic



180
Million Years Ago

Ron Blakey
Northern Arizona
University

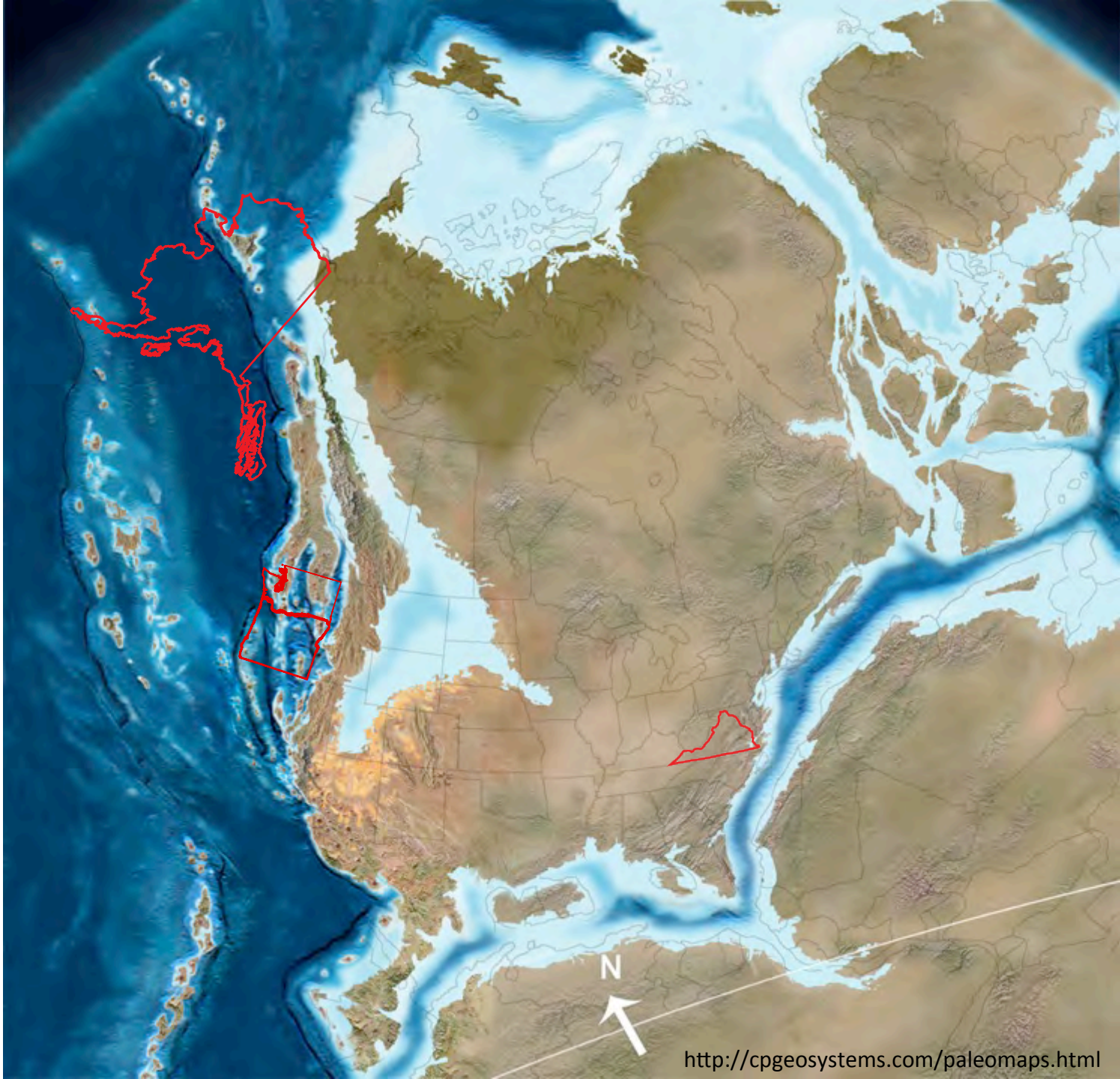
http://cpgeosystems.com/paleomaps.html

Jurassic

170

Million Years Ago

Ron Blakey
Northern Arizona
University



http://cpgeosystems.com/paleomaps.html

Jurassic

150

Million Years Ago

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University

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Cretaceous

140

Million Years Ago

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Northern Arizona
University

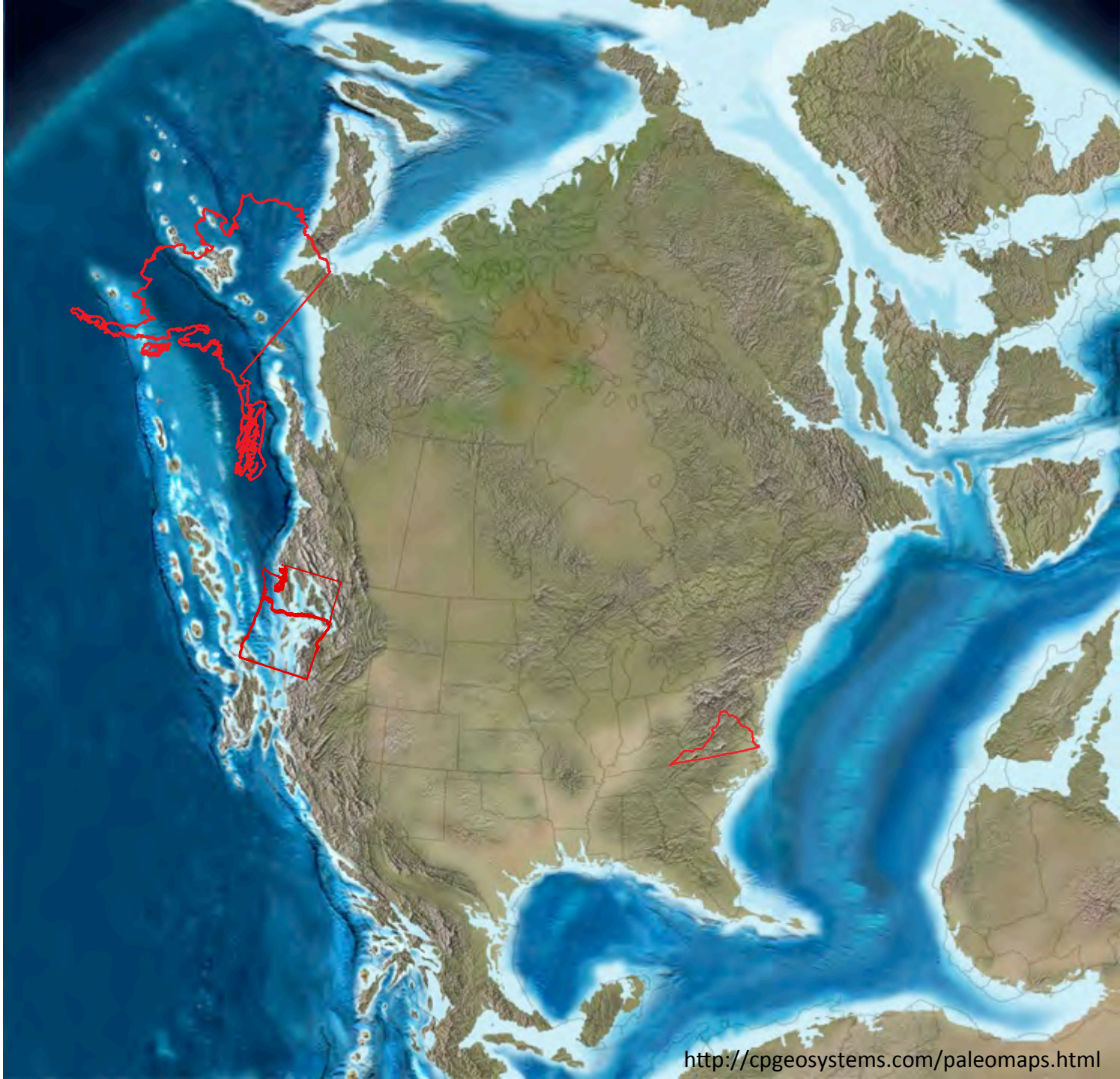
http://cpgeosystems.com/paleomaps.html

Cretaceous

130

Million Years Ago

Ron Blakey
Northern Arizona
University



http://cpgeosystems.com/paleomaps.html

Cretaceous

115

Million Years Ago

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Eocene

50

Million Years Ago

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Eocene

40

Million Years Ago

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Oligocene

25

Million Years Ago

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Miocene

15

Million Years Ago

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Miocene

8

Million Years Ago

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Pliocene

3

Million Years Ago

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Northern Arizona University

Holocene

12,500
Years Ago

Ron Blakey
Northern Arizona
University

Now

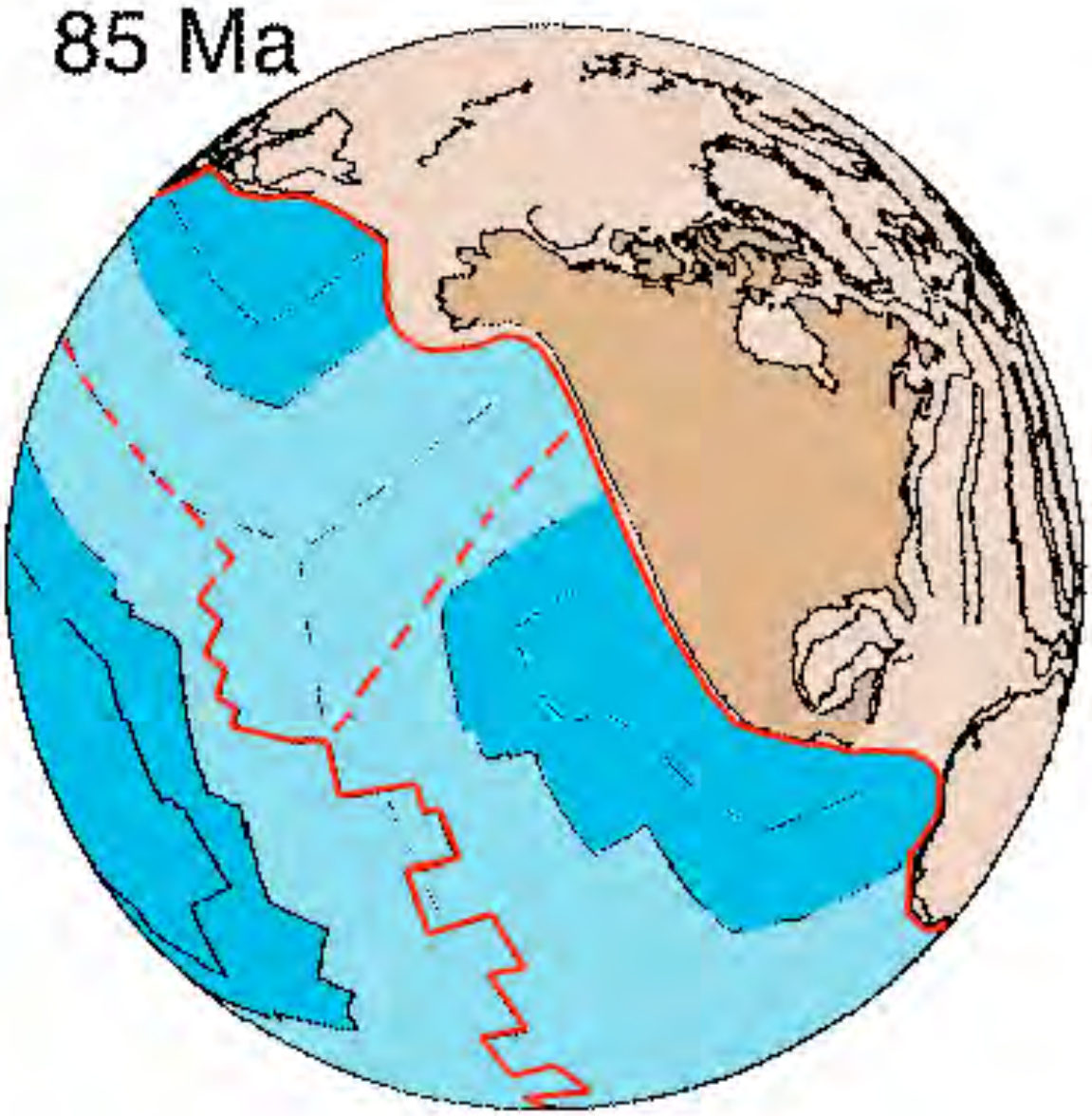
Present Day

Ron Blakey
Northern Arizona University

http://cpgeosystems.com/paleomaps.html

Tectonic Development of Western North America

85 Million Years Ago to the Present

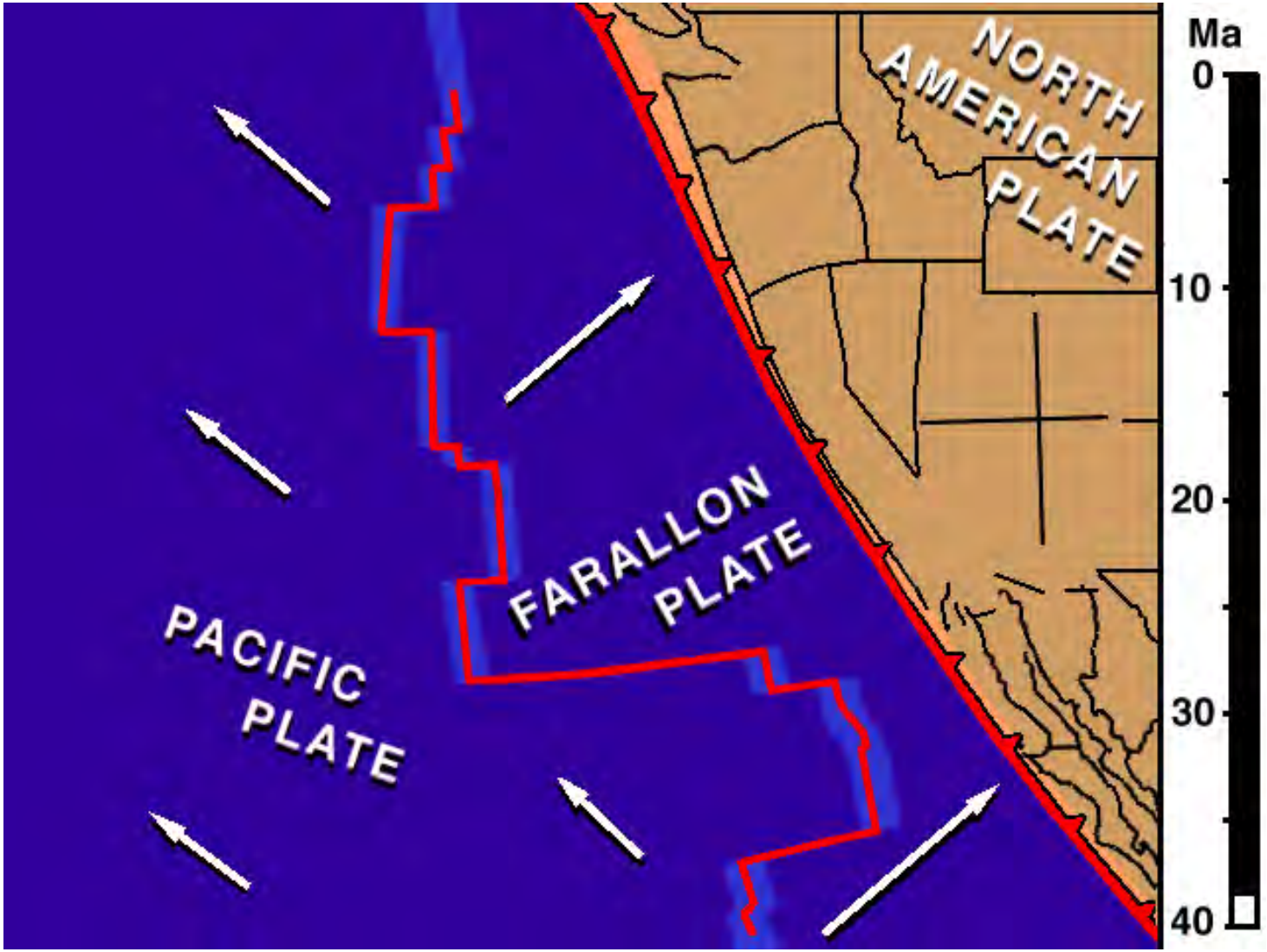


From: Tanya Atwater

Educational Multimedia Visualization Center
Department of Earth Science
University of California at Santa Barbara

http://emvc.geol.ucsb.edu

Tectonic Development of the Pacific Northwest
40 Million Years Ago to the Present

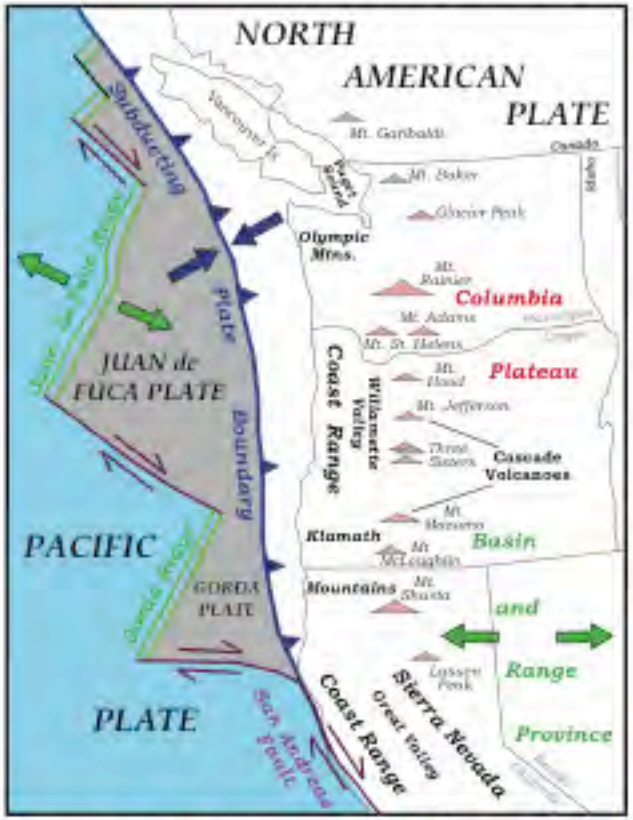


From: Tanya Atwater

Educational Multimedia Visualization Center
Department of Earth Science
University of California at Santa Barbara

http://emvc.geol.ucsb.edu

PLATE TECTONICS OF THE PACIFIC NORTHWEST



Cascadia Subduction Zone

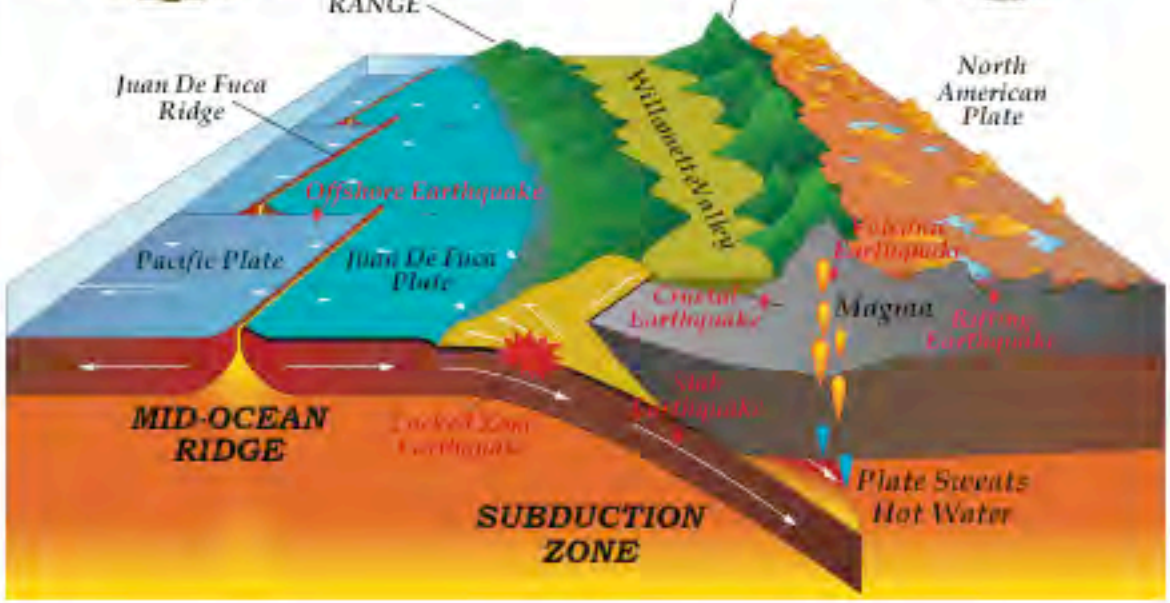


Plate Boundaries:
Hotspot
Divergent
Convergent
Transform

Cascadia EarthScope Earthquake and Tsunami Education Program (CEETEP)

Workshop for K-12 Teachers, Park/Museum Interpreters, and Emergency Management Educators

October 11-14, 2013

Clatsop Community College

Astoria, Oregon

PLATE BOUNDARIES

- **Divergent**:
  - *Plates move away from one another.*
  - *Volcanoes and Shallow Earthquakes*

- **Convergent**:
  - *Plates move toward one another.*
  - *Volcanoes and very large earthquakes*

- **Transform**:
  - *Plates slide past one another.*
  - *Earthquakes but no volcanoes*

- **(Hotspot)**:
  - *Plate rides over plume of hot mantle.*
  - *Lots of volcanism.*