

EarthScope Overview

“Beauty and the Beast: Plate Tectonics, Landscape Development, and Geological Hazards of the United States”



www.earthscope.org

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Oregon State University

Exploring Southwest Geology and Geophysics through the EarthScope Program
Geophysical Institute
University of Texas, Austin
May 20-21, 2011

Beauty and the Beast: Plate Tectonics, Landscape Development, and Geological Hazards of the United States

Goals

1. To provide Southwest teachers with an overview of the tectonic processes responsible for the spectacular landscapes of the United States.
2. To introduce the teachers to efforts by EarthScope to monitor active Earth processes that form the landscape and cause earthquakes and other natural hazards.




Beauty and the Beast: Plate Tectonics, Landscape Development, and Geological Hazards of the United States

Objectives

Teachers will be able to:

1. Describe EarthScope’s three observatories and give examples of how each monitors the active Earth.
2. Discuss tectonic processes responsible for the landscape of a region of the US and describe how seismic and GPS instruments reveal the region’s deep structure and ongoing tectonic activity.



EarthScope

- Funded by the [National Science Foundation](#)
- A collaborative effort by the [Incorporated Research Institutions for Seismology \(IRIS\)](#), [UNAVCO](#), and [Stanford University](#), with contributions from the U. S. Geological Survey, NASA, and other organizations













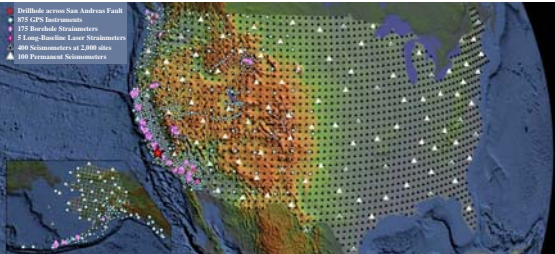

EarthScope

A nationwide effort to

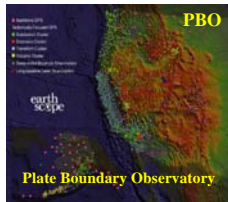
- Explore the structure and evolution of North American continent
- Study processes that cause earthquakes and volcanic eruptions

EarthScope has three main “observatories”

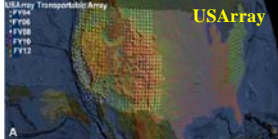
- Drift hole across San Andreas Fault
- 172 GPS Instruments
- 175 Broadband Seismometers
- 51 Long Baseline Laser Seismometers
- 400 Seismometers at 2,000 sites
- 100 Permanent Seismometers




EarthScope Observatories



Geodetic Instruments



USArray
Seismometers



Deep Drillhole

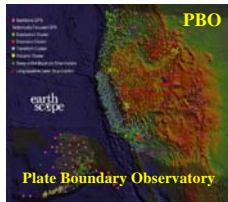



Plate Boundary Observatory



San Andreas Fault Observatory at Depth

EarthScope

Like a “Hubble Telescope” aimed into the Earth

• Distributed across San Andreas Fault
 • 875 GPS Instruments
 • 175 Broadband Seismometers
 • 5 Long-Baseline Laser Seismometers
 • 400 Seismometers at 2,000 sites
 • 100 Permanent Seismometers

Informal Education Workshops

For Interpretive Professionals in Parks and Museums
Monitoring the Dynamic Landscape Enhances our “Sense of Place”
National Parklands

Informal Education Workshops

For Interpretive Professionals in Parks and Museums

6. New Madrid - Central U.S.

- March 17-20, 2011
- 200th Anniversary of Big Earthquakes
- USArray Rolling across the Midwest

www.earthscope.org/enp/parks

EarthScope New Madrid–Central U.S. Interpretive Workshop

Beauty and the Beast

“The same geological processes that threaten our lives with earthquakes and other geological hazards also nourish our spirits by creating the inspiring landscapes of the United States.”

Starved Rock State Park, Illinois
<http://www.illinois.gov/education/indianmuseums/centralnewspark.htm>

Clearing the river after the New Madrid earthquakes
<http://www.earthscope.org/enp/parks>

Park Lands: East vs. West

- Why are there more National Park lands in the West compared to the East?
- Why is the topography more rugged in the West compared to the East?

Parks and Plates
©2007 Robert J. Lister

PLATE TECTONICS

- **Tectonics:**
- From the Greek “*teuton*”
 - builder
 - “architect”
- The study of large features on Earth’s surface and the processes that form them.

“PLATE TECTONICS”

- **Large features:**
 - continents
 - ocean basins
 - mountain ranges
- **and processes:**
 - earthquakes
 - volcanic eruptions
- **due to movement of plates of Earth's outer shell.**

Cracked Egg Shell!

Parks and Plates
©2005 Robert J. Lillie

Plate Boundaries

Earthquakes (yellow dots)
Active Volcanoes (orange triangles)

http://www.geo.utep.edu/kidd/Vol_eq_plates.html

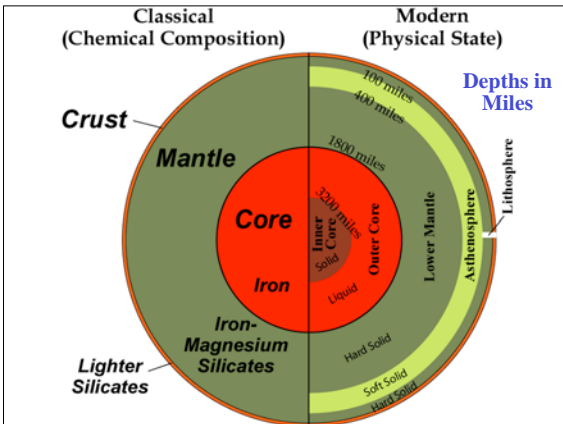
Landscapes of national parks due to processes:

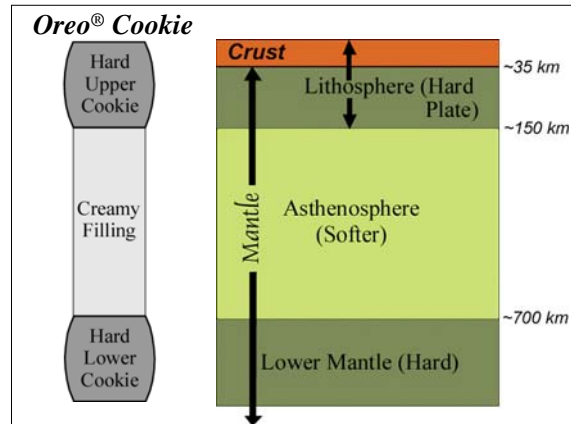
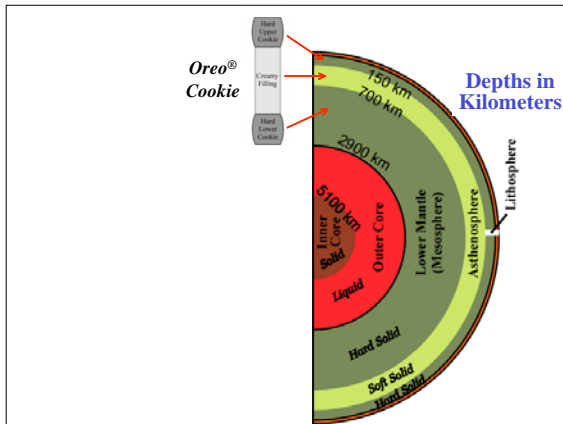
- **At plate boundaries**
 1. Where they pull apart (**divergent**)
 2. Where they crash together (**convergent**)
 3. Where they slide past one another (**transform**)
- **And at hotspots**

The Whole Earth and Plate Tectonics

We need to understand what goes on inside the Earth.

National Geographic and Photo: Earthrise.com





Oreo® Psycho-Personality Test

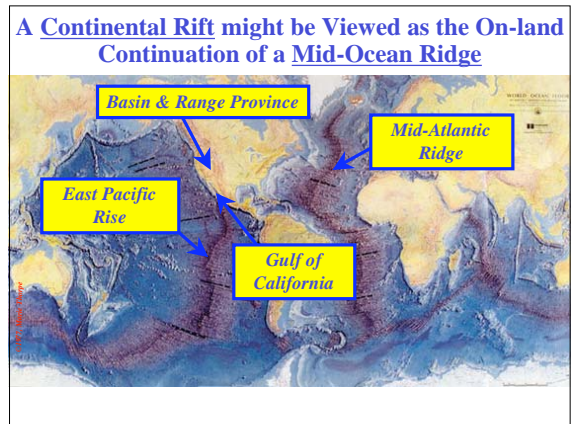
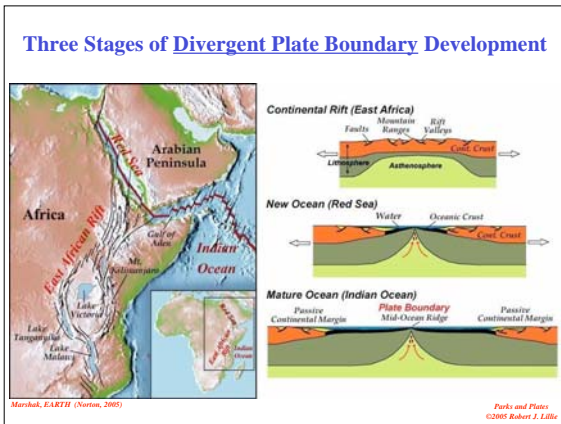
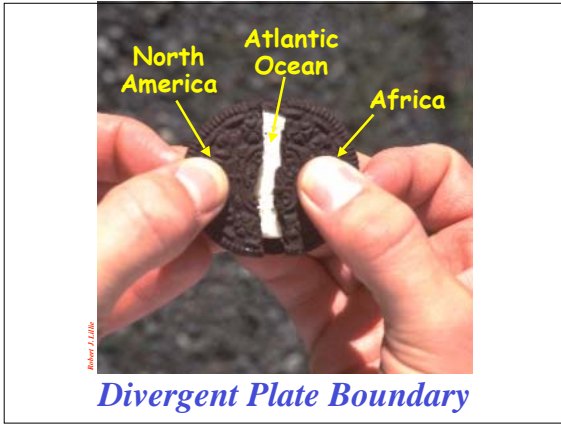
www.superkids.com/aweb/pages/humor/050199.sht

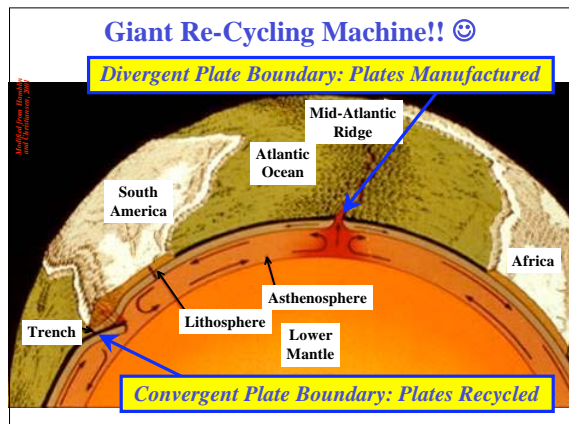
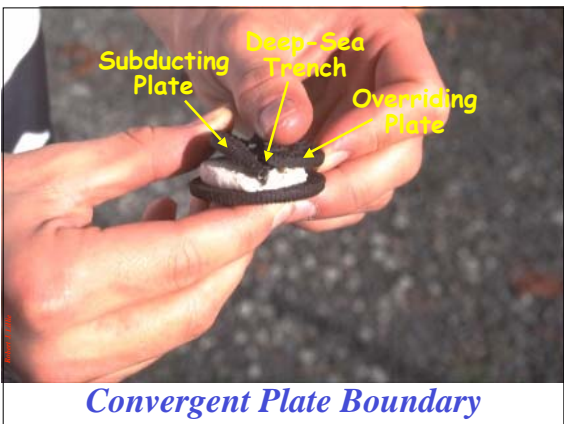
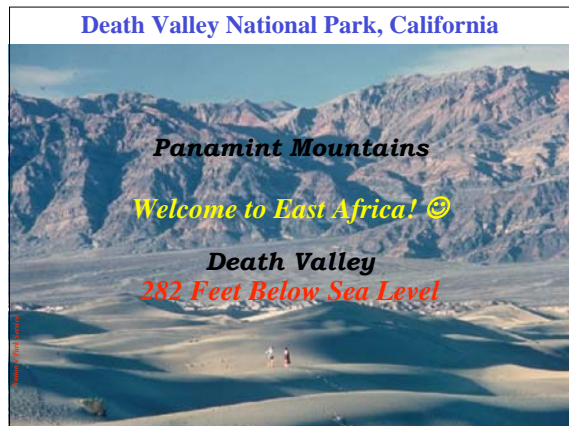
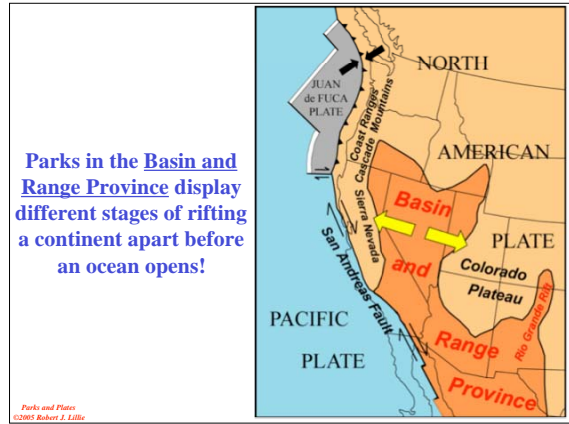
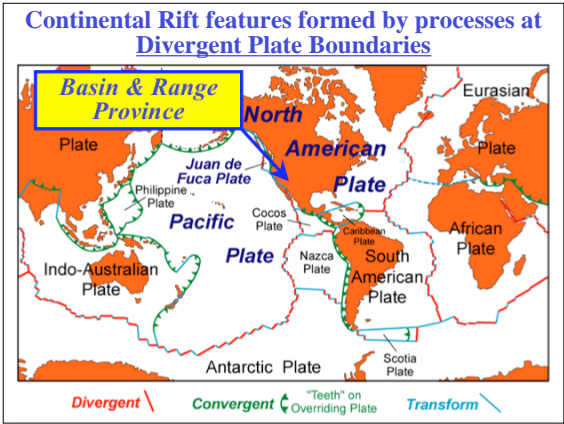
- Psychologists have discovered that the manner in which people eat Oreo® cookies provides great insight into their personalities. Choose which method best describes your favorite method of eating Oreos:
- 1. The whole thing at once.
- 2. One bite at a time.
- 3. Slow and methodical nibbles examining 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.





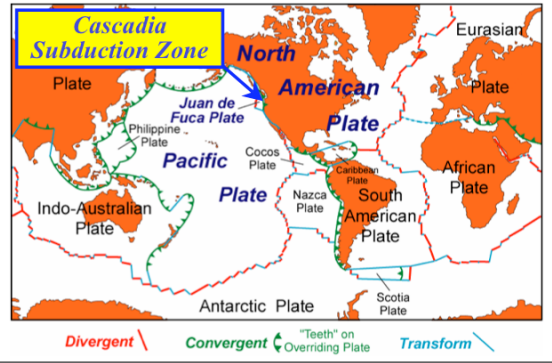


Andes Mountains, South America



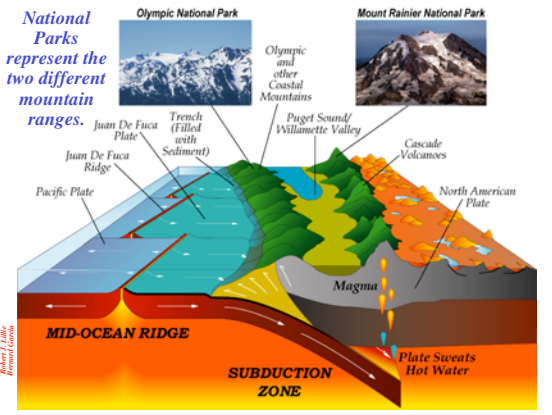
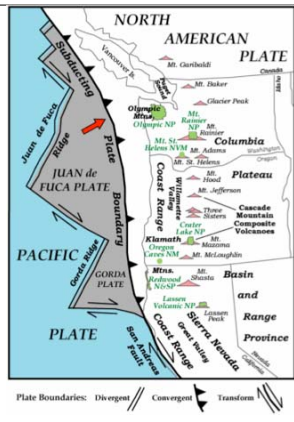
Osorno volcano near Puerto Montt, Chile
<http://whatonearth.olehmielsen.dk/volcanoes.asp>

Subduction Zone features formed by processes at Convergent Plate Boundaries



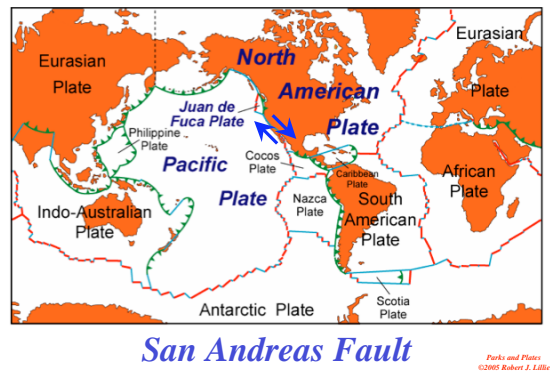
Parks in the Pacific Northwest Display Convergent Plate Boundary Motion

Some Park Lands in the Cascadia Subduction Zone



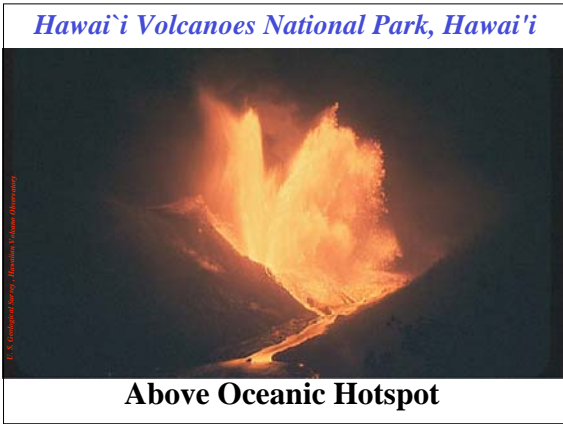
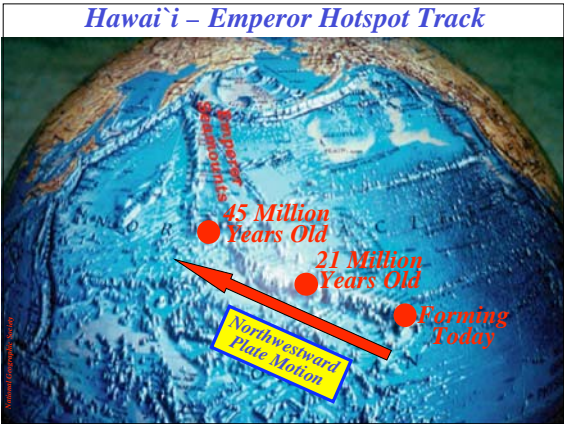
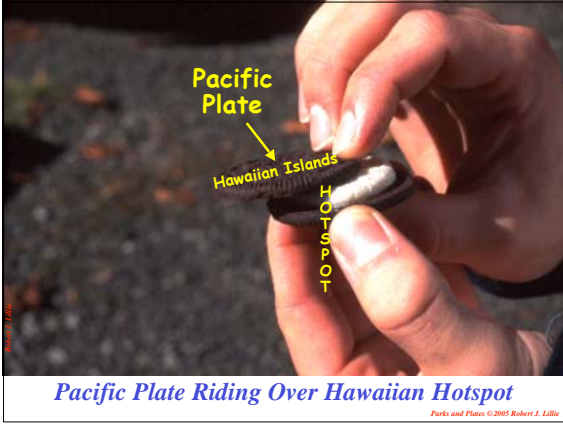
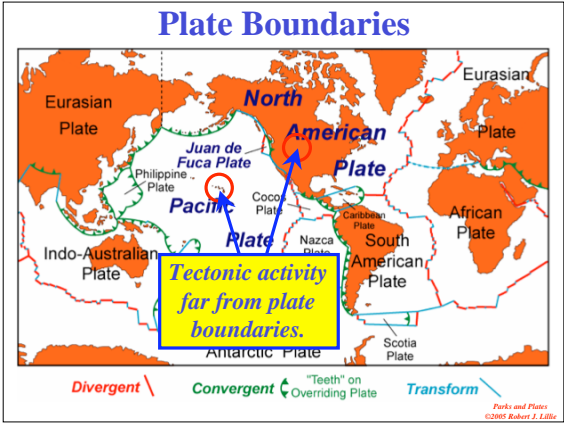
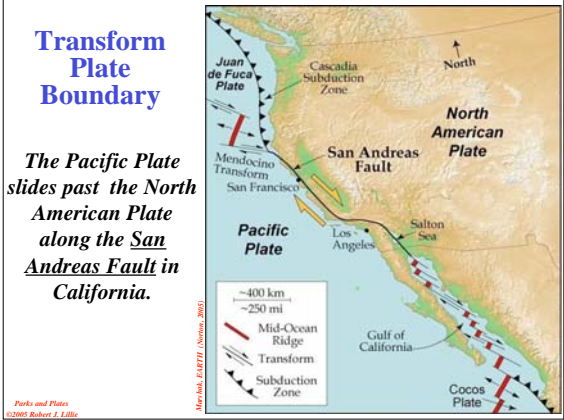
Transform Plate Boundary

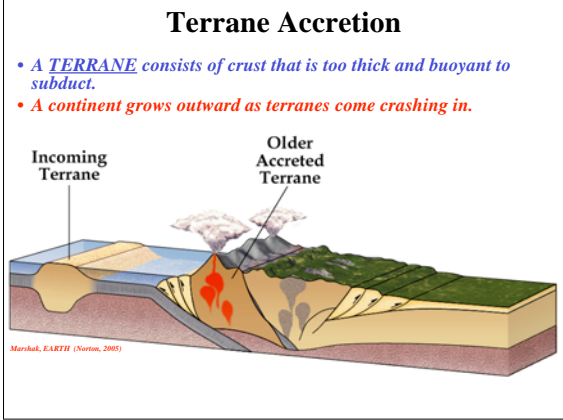
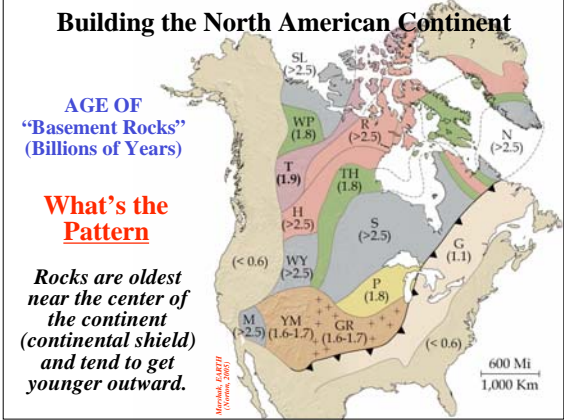
Transform Plate Boundary

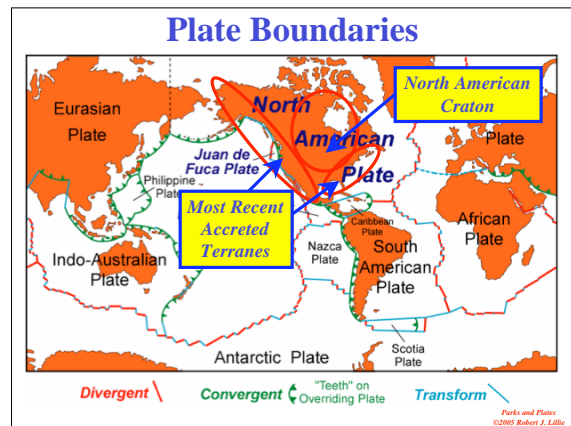
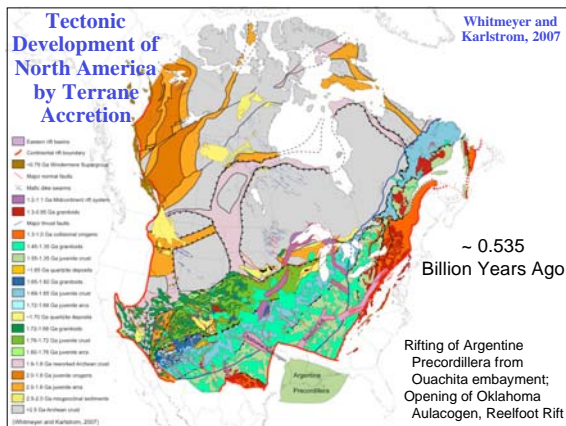
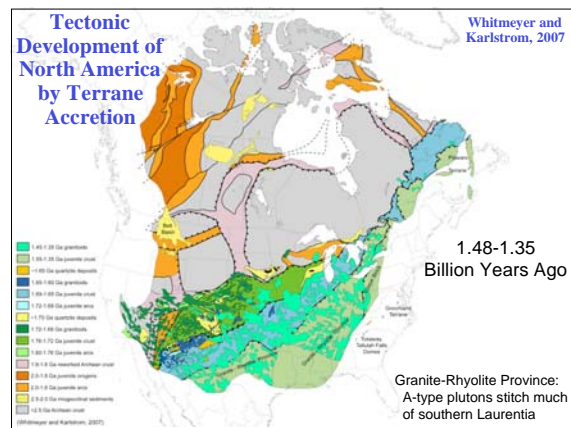
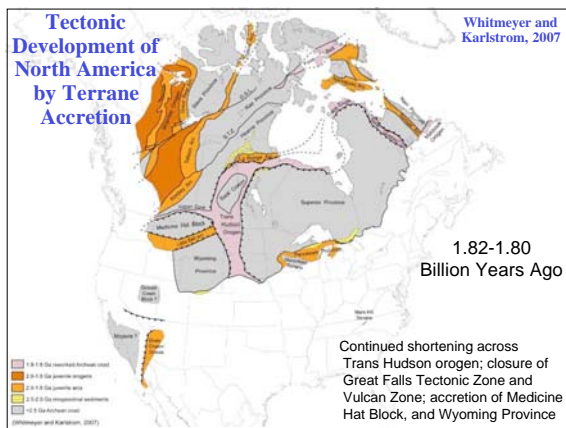


San Andreas Fault

Parks and Plates
 ©2001 Robert J. Little







EarthScope Interpretive Themes

- The EarthScope experiment—the most comprehensive exploration to date of the structure, dynamics, and geologic history of the North American continent—exemplifies the insatiable human drive to learn.
- EarthScope encourages a feeling of national interconnectedness—a continental sense of place—by openly inviting communities to actively participate in the experiment, and by fostering an understanding that their local environment and culture interact with other components within the larger, dynamic Earth system.

Bootheel Youth Museum, Malden, Missouri

<http://www.bootheelyouthmuseum.org>

1. USArray

Observatories

USArray:

- Includes 400 Transportable Seismometers
- Each station occupies a site for 1½ to 2 years
- 10 years to leap-frog across the country

IRIS
(Incorporated Research Institutions for Seismology)
Washington, DC

http://anf.ucsd.edu/stations/deployment_history.php

1. USArray

Observatories

Transportable Array (TA):
 2004 → 10th Anniversary of Northridge Earthquake
 2011-12 → 200th Anniversary of New Madrid Earthquakes
 2014 → 50th Anniversary of Great Alaska Earthquake

2010-2013

2013-2018

- ~ 1000 stations so far
- ~ 700 to go

http://anf.ucsd.edu/stations/deployment_history.php

1. USArray

Observatories

May, 2011

Legend:
 Transportable Array (red dot)
 Reference Network (blue dot)
 Flexible Array (green dot)
 Magnetotelluric (yellow dot)

GPS 2011 May 11 12:03:50

Visualizations

Visualization of Seismic Waves Moving Across USArray

Wells, Nevada, 2008

Bob Woodward - IRIS
Chuck Ammon - Penn State

February 21, 2008, NEVADA, Mw6.0

2008 02 14 16:02

S16A (47°)

Seconds After Earthquake

Visualizations

Animation of Wenchuan China Earthquake

Robert Woodward IRIS

Visualization of Seismic Waves Moving Across USArray

China, 2008

Bob Woodward - IRIS

www.earthscope.org

Visualizations

Visualization of Seismic Waves Moving Across USArray - 3D

China, 2008

**Bob Woodward - IRIS
Chuck Ammon - Penn State**

Informal Education Workshops

For Interpretive Professionals in Parks and Museums

5. Yellowstone - Snake River Plain - Teton Region

- with University of Utah
- Teton Science Schools
- Sept. 9-12, 2010

www.earthscope.org/enp/parks

EarthScope Yellowstone - Snake River Plain - Teton Interpretive Workshop

Field Trip to EarthScope Seismic, GPS, and Strainmeter Site in Yellowstone National Park

September 10, 2010

EarthScope Yellowstone - Snake River Plain - Teton Interpretive Workshop

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6. New Madrid - Central U.S.

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www.earthscope.org/enp/parks

EarthScope New Madrid -- Central U.S. Interpretive Workshop, March 17-20, 2011

One Person Jumping

~ 30 People Jumping

Jer-Sing Chiu, University of Memphis

To generate earthquakes, there must be:

- Faults that slip suddenly
- Force (stress) to cause motion along the faults

At plate boundaries:

- There are many faults
- Plate motions provide stress that causes motion

What about within the interior of plates?

NMSZ
less than 1 mm/yr

Earthquakes
● M5
○ M6
○ M7

Seth Stein, Northwestern University

Intra-Continental Tectonics

- Over billions of years, continents retain structures formed by rifting, collisions, failed rifts, basin formation, faulting, etc.
- Stresses within the plate—from various sources—can reactivate these features and cause intraplate earthquakes.
- A set of **failed rifts** are associated with the **New Madrid and Wabash Valley** seismic zones.

Reelfoot Rift

Rough Creek Graben

Map from Steve Marshak

Seth Stein, Northwestern University

EarthScope

Like a “Hubble Telescope” aimed into the Earth ☺

USArray

Like taking CatScans or Ultrasounds of North America

Red → Seismic Waves Travel Slow (Young, Hot, “Soft”)

Blue → Seismic Waves Travel Fast (Old, Cold, “Hard”)

Goes and van der Lee (2001), van der Lee et al. (2002)

earth scope

CAT Scan

Computed Axial Tomography

earth scope

Seismic Tomography

Using earthquakes to image Earth’s interior

Seismic Tomography → “CatScan” of the Earth

P-Wave “Community Velocity Model” based partly on USArray through November 2007

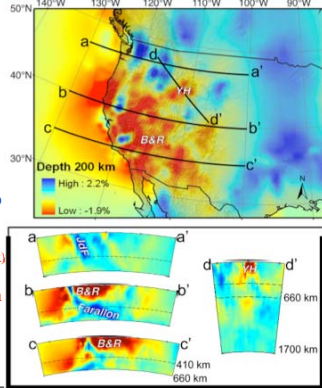
High Velocity (Blue):

- Eastern U. S.
 - Subducted Juan de Fuca (JdF) and Farallon plates
- Cold → Waves Speed Up

Low Velocity (Red):

- Basin and Range Province (B&R)
 - Yellowstone Hotspot (YH)
- Hot → Waves Slow Down

Burdick and others, 2008



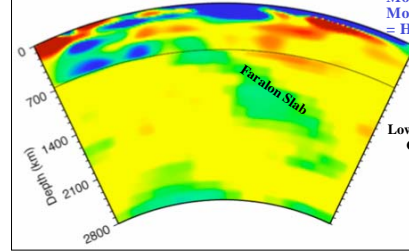
Seismic Tomography



Like a digital camera:
More “pixels”
More closely-spaced pixels
= Higher Resolution

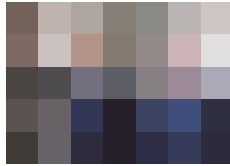
Upper mantle from Van der Lee and Frederiksen (2005)

Lower mantle from Grand (2002)



Seismic Tomography

Like a digital camera:



Seismic Tomography

Like a digital camera:
More “pixels”



Seismic Tomography

Like a digital camera:

More “pixels”

More closely-spaced pixels

= Higher Resolution!



Seismic Tomography → “CatScan” of the Earth

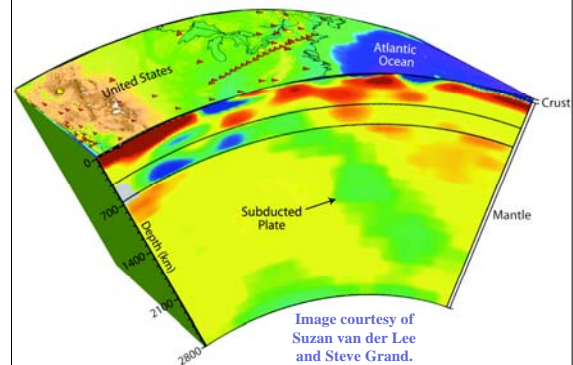
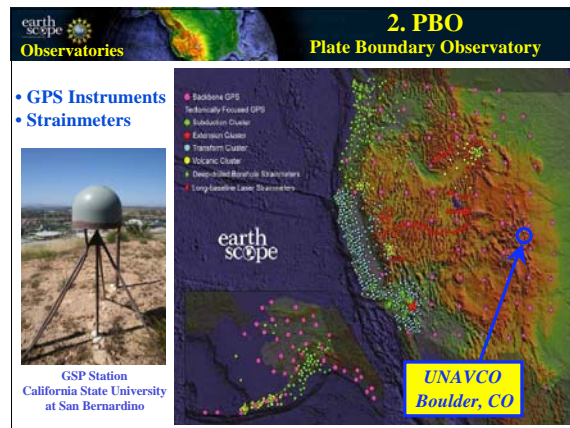
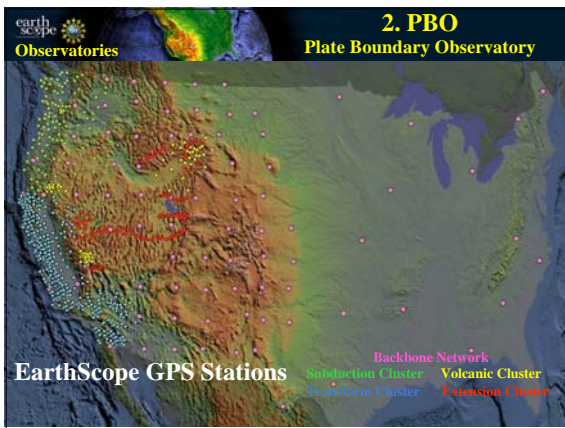
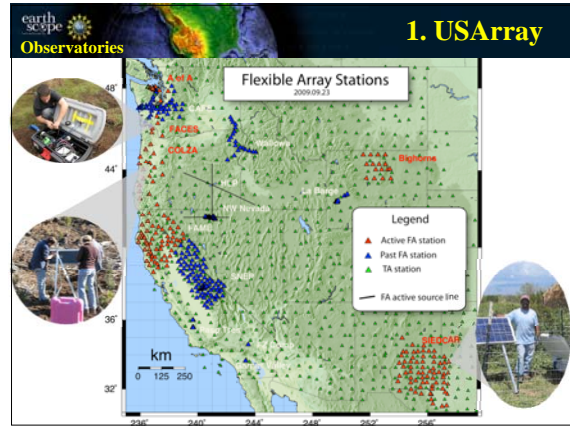
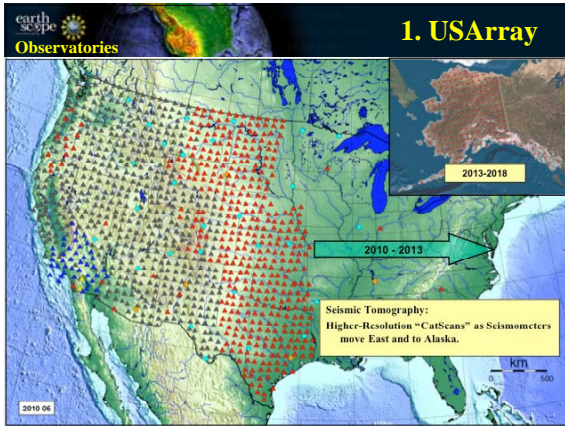


Image courtesy of Suzan van der Lee and Steve Grand.



earth scope

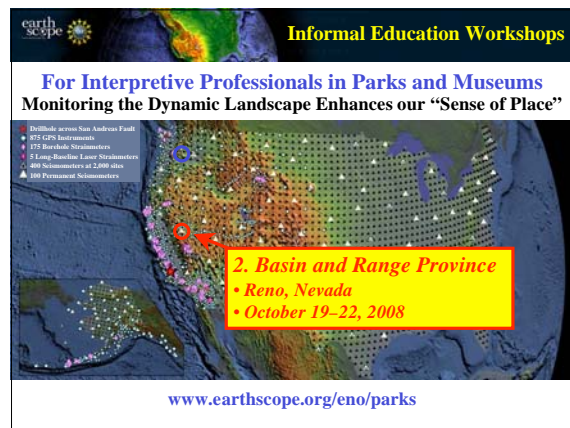
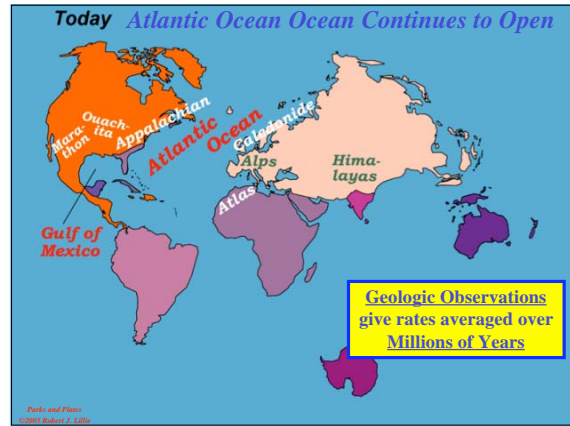
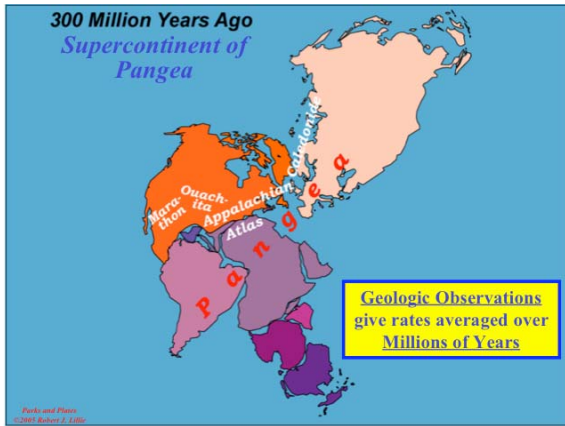
From UNAVCO Teacher Workshop

Wegener's Dream

"This [direct measurement of continental drift] must be left to the geodesists. I have no doubt that in the not too distant future we will be successful in making a precise measurement of the drift of North America relative to Europe." -- Alfred Wegener, 1929

200 million years ago all of the present-day continents combined to form a single supercontinent called Pangaea.





Basin and Range Workshop

University of Nevada – Reno
October, 2008

Plate Boundary Observatory
GPS Station
Slide Mountain, Nevada

Brian Wernicke, Cal Tech



Basin and Range Workshop

University of Nevada – Reno
October, 2008

Plate Boundary Observatory
GPS Station
Slide Mountain, Nevada

Brian Wernicke, Cal Tech



We're not standing still ...

PBO – GPS
Slide Mountain,
Nevada



*EarthScope Workshop for Interpretive Professionals
in the Basin and Range Province, 2008*

We're moving away from Kansas ☺

PBO – GPS
Slide Mountain,
Nevada



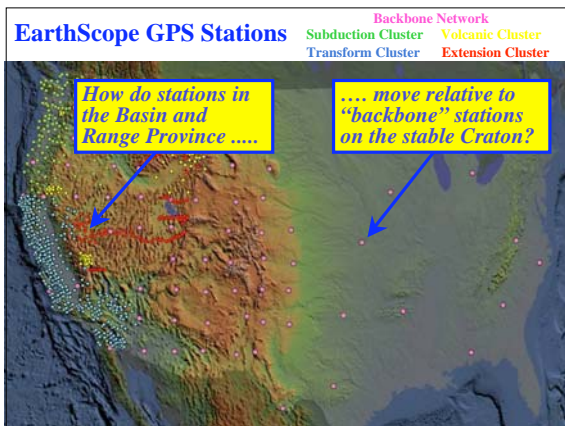
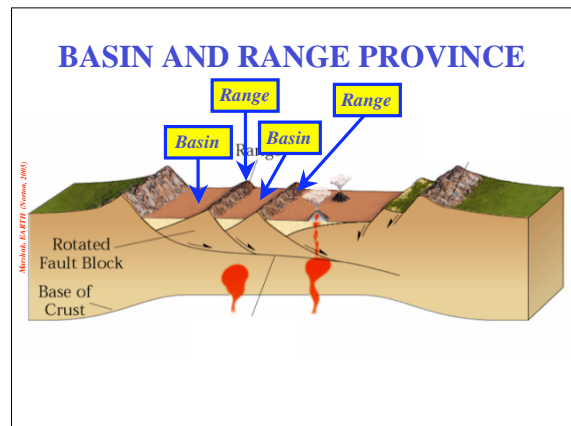
*EarthScope Workshop for Interpretive Professionals
in the Basin and Range Province, 2008*

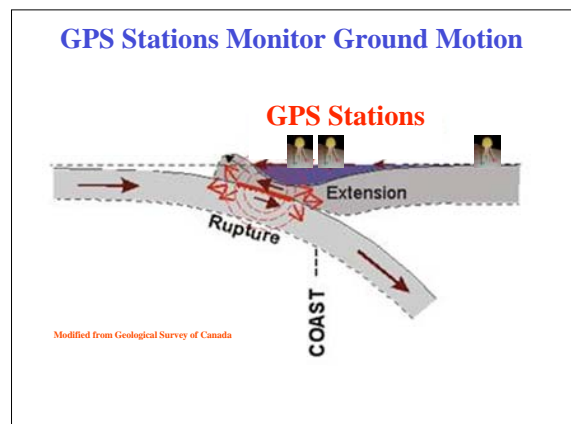
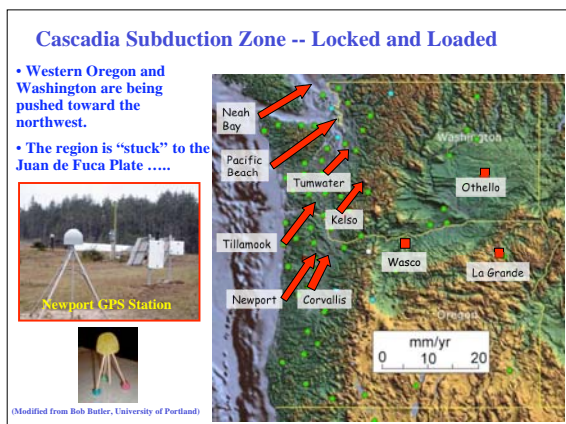
EarthScope GPS Stations

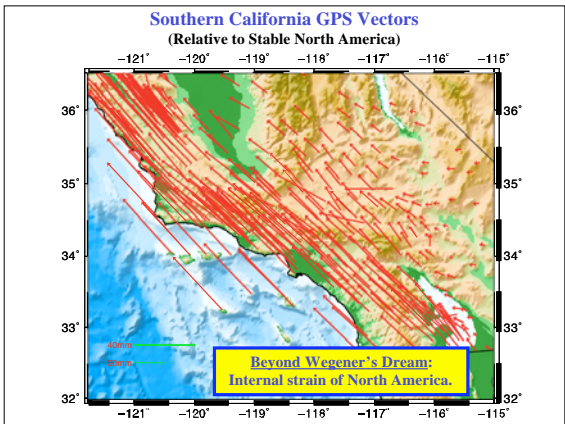
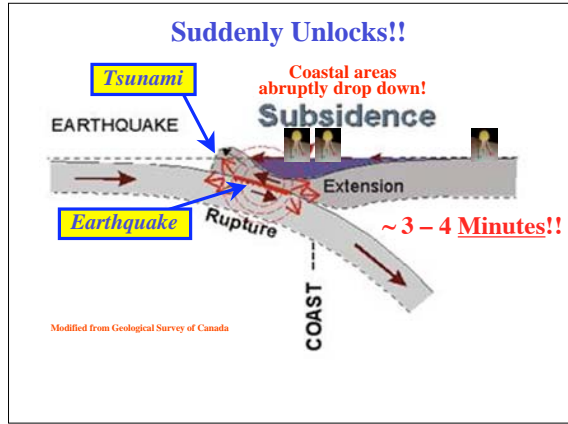
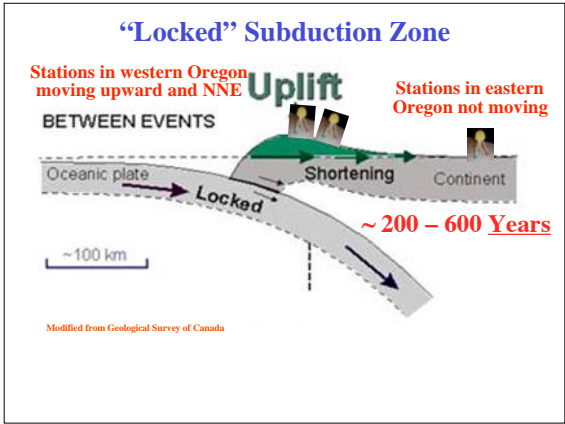
Backbone Network
Subduction Cluster Volcanic Cluster
Transform Cluster Extension Cluster

How do stations in the Basin and Range Province

.... move relative to "backbone" stations on the stable Craton?





Creating the SAN ANDREAS FAULT with a Deck of Cards

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

Broad Zone of Shearing

Parks and Plates
©2005 Robert J. Lillo
Robert J. Lillo

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.

San Andreas Fault

Parks and Plates
©2005 Robert J. Lillo
Robert J. Lillo

