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**Title:** How did the New Mexico get its Mountains, Valleys, and Volcanos and how do Earthquakes get triggered?

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# How did the New Mexico get its Mountains, Valleys, and Volcanos and how do Earthquakes get triggered?

Los Alamos Judicial Science School, 2023

**Andrew A. Delorey**



# Contents

- What are the interesting geologic features in New Mexico?
- How did New Mexico get this way?
- What are triggered earthquakes?



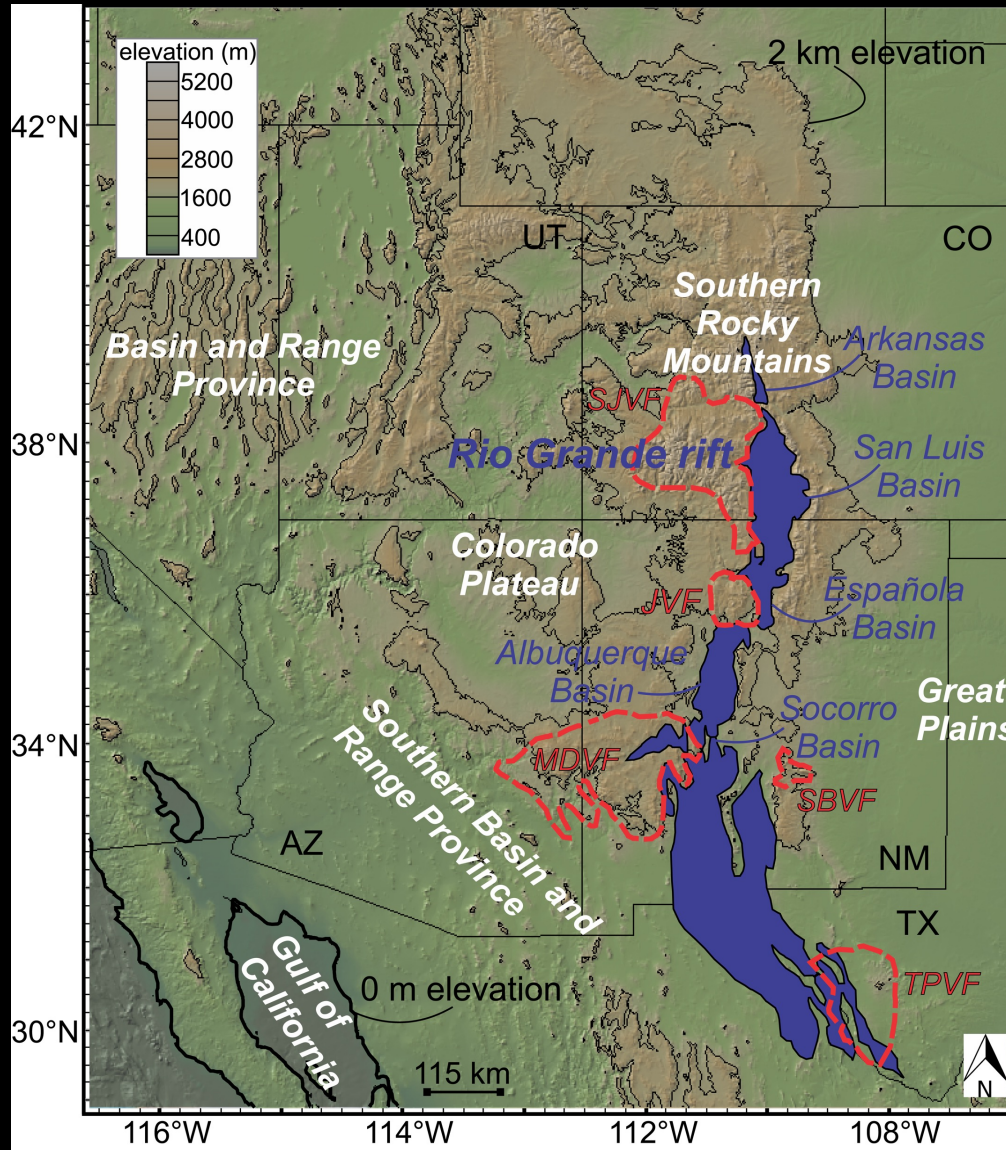
Terms to remember to bring up at your next dinner party to sound like a geophysicist.

- Rio Grande Rift
- Colorado Plateau
- Basin and Range
- Volcanic Lineament

# Why is the Rio Grande Rift interesting?

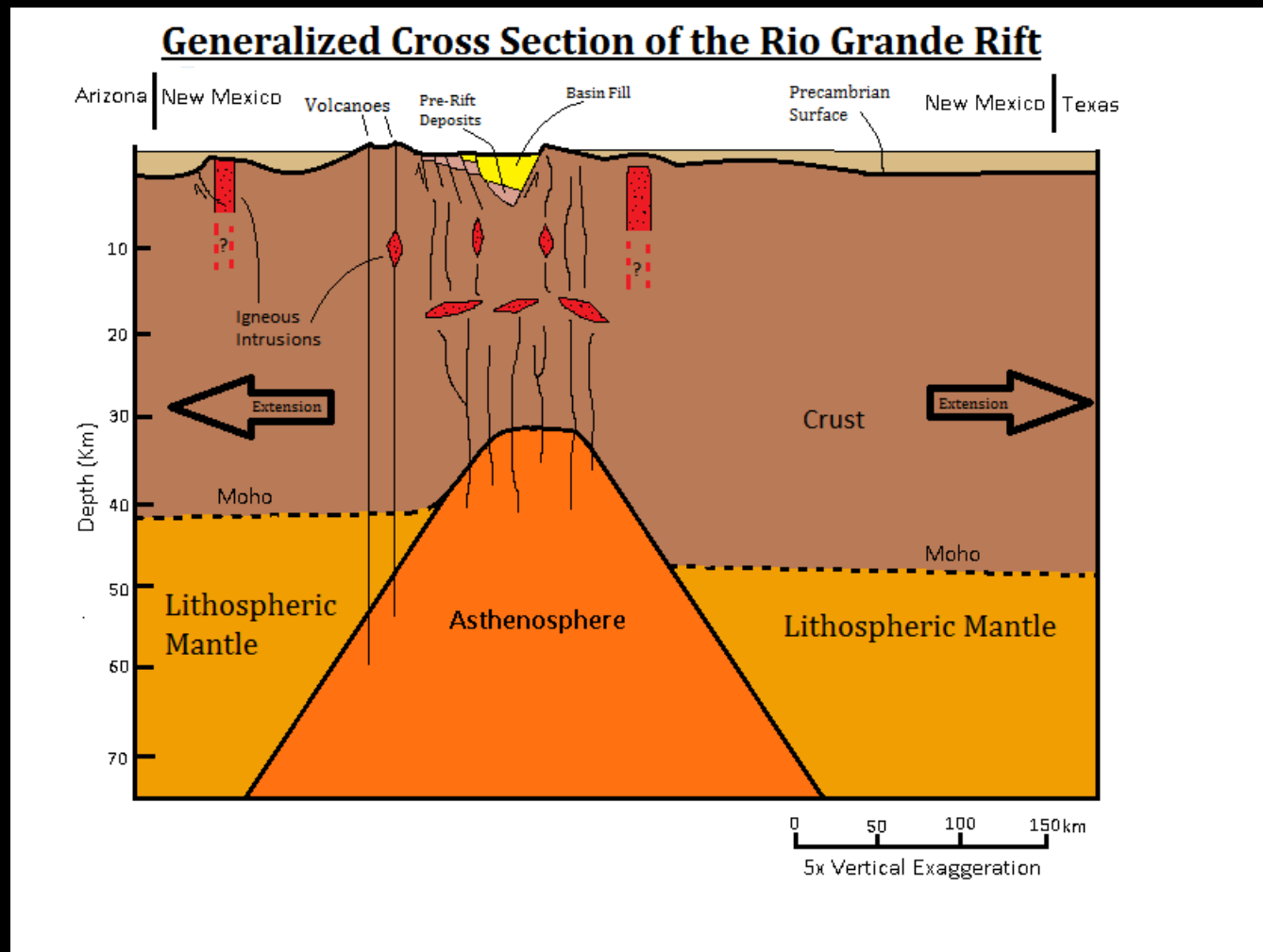
- Many volcanos
- Why the Rio Grande is where it is
- The Earth's crust is splitting apart!  
(very, very slowly, mm/year)
- Hot springs (Ojo Caliente, etc.)

# Rio Grande Rift



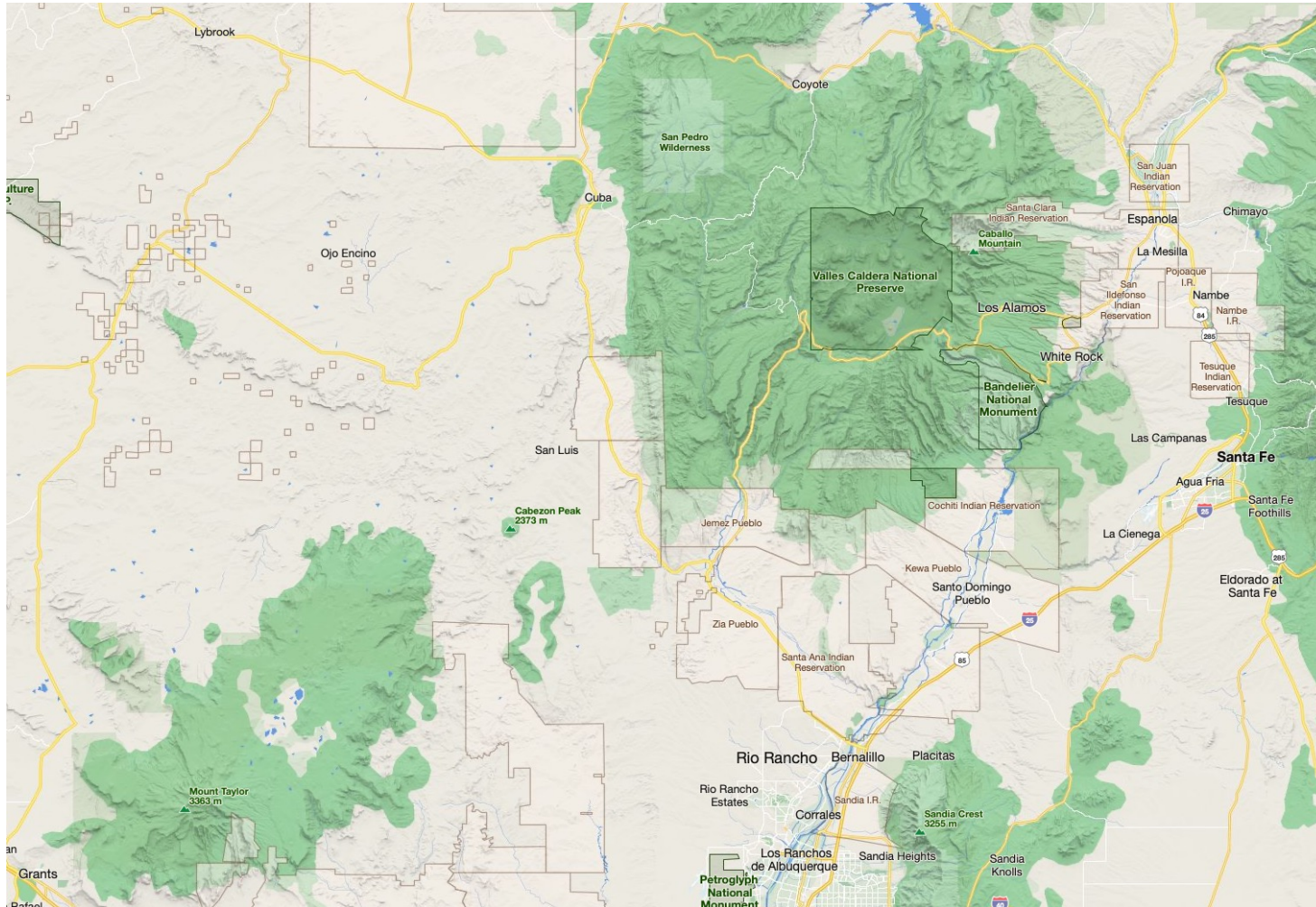
Wijk et al [2018]

# Rio Grande Rift



Baldrige et al [1984]

# Jemez Volcano, Mount Taylor



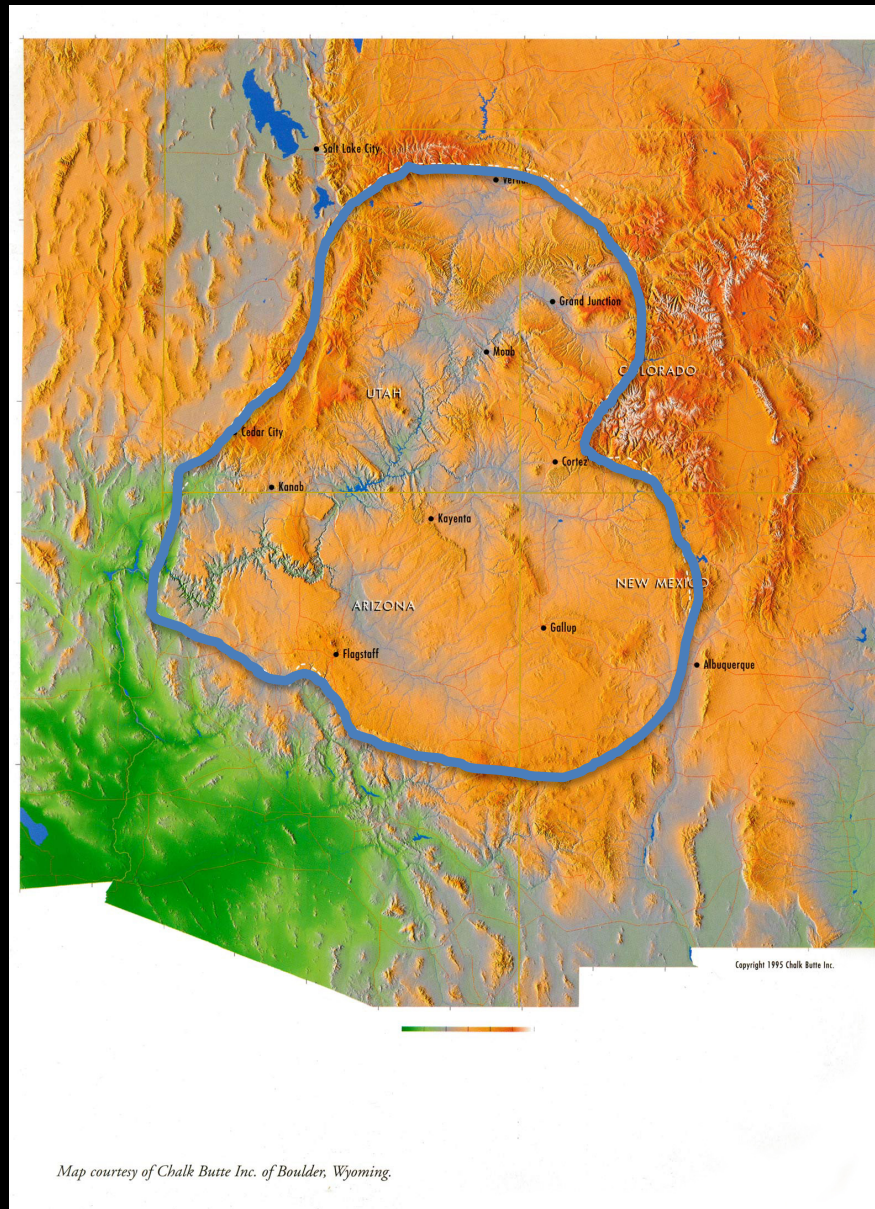
# Taos Plateau Volcanos



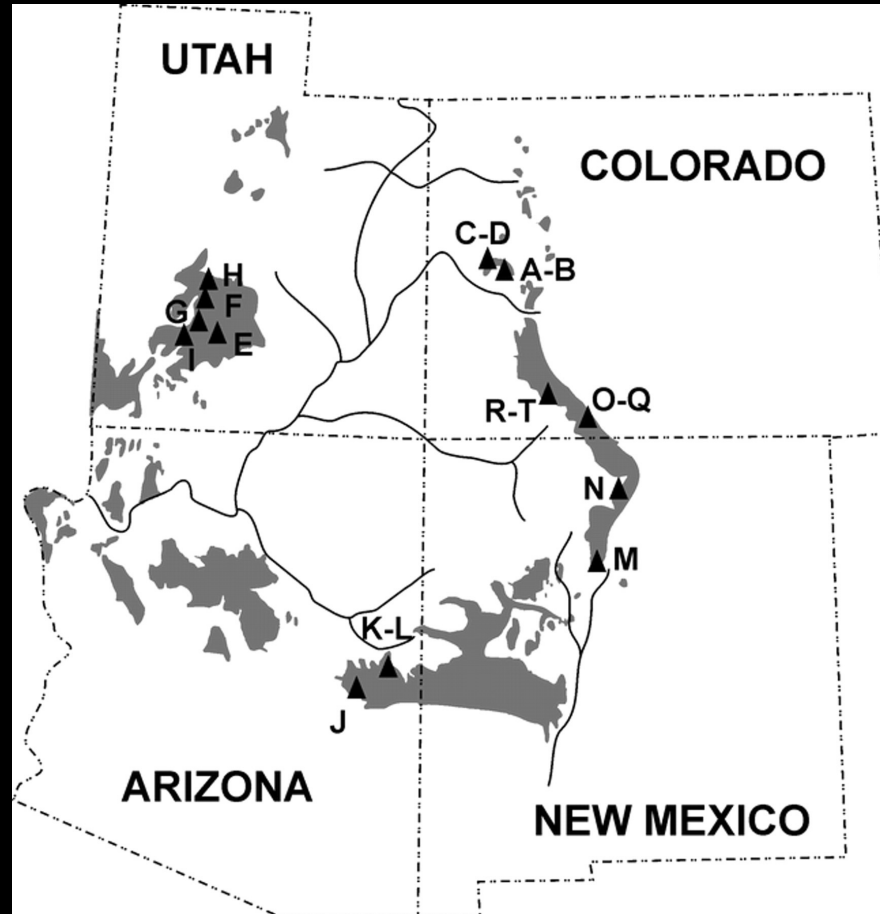
# Why is the Colorado Plateau interesting?

- It has been stable for at least 600 million years
  - The Earth is 4.5 billion years old
  - Complex life arose around 540 million years ago.
  - Humans have been around for about 200 thousand years.
- Regions around the Colorado Plateau are much more deformed and altered.
- Currently, the Colorado Plateau has a high elevation (~2 km), but it has been below sea level in the past.
- The Grand Canyon exists because it is the location where the Colorado River drains off of the Colorado Plateau

# Colorado Plateau



# Colorado Plateau Volcanos



# Colorado Plateau 66-100 Million Years Ago



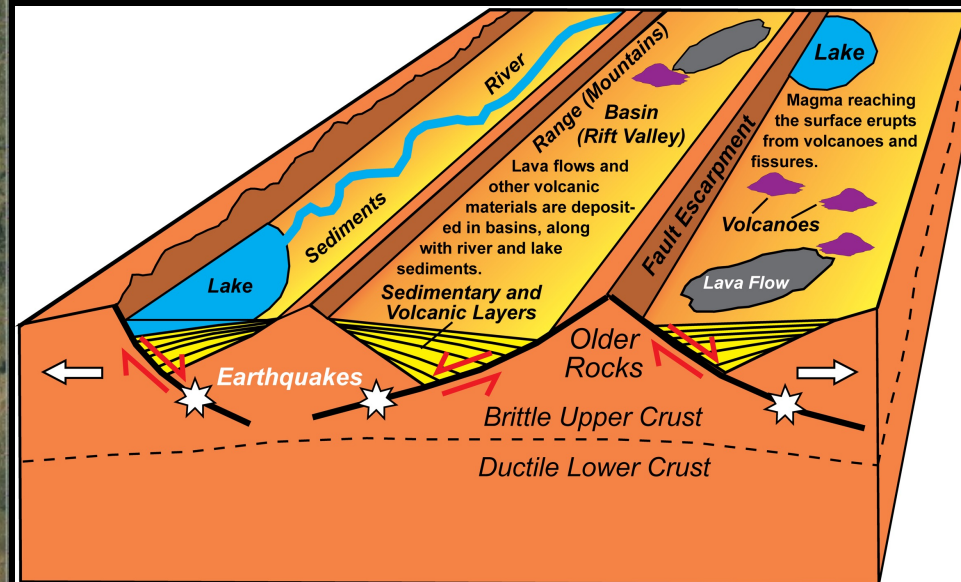
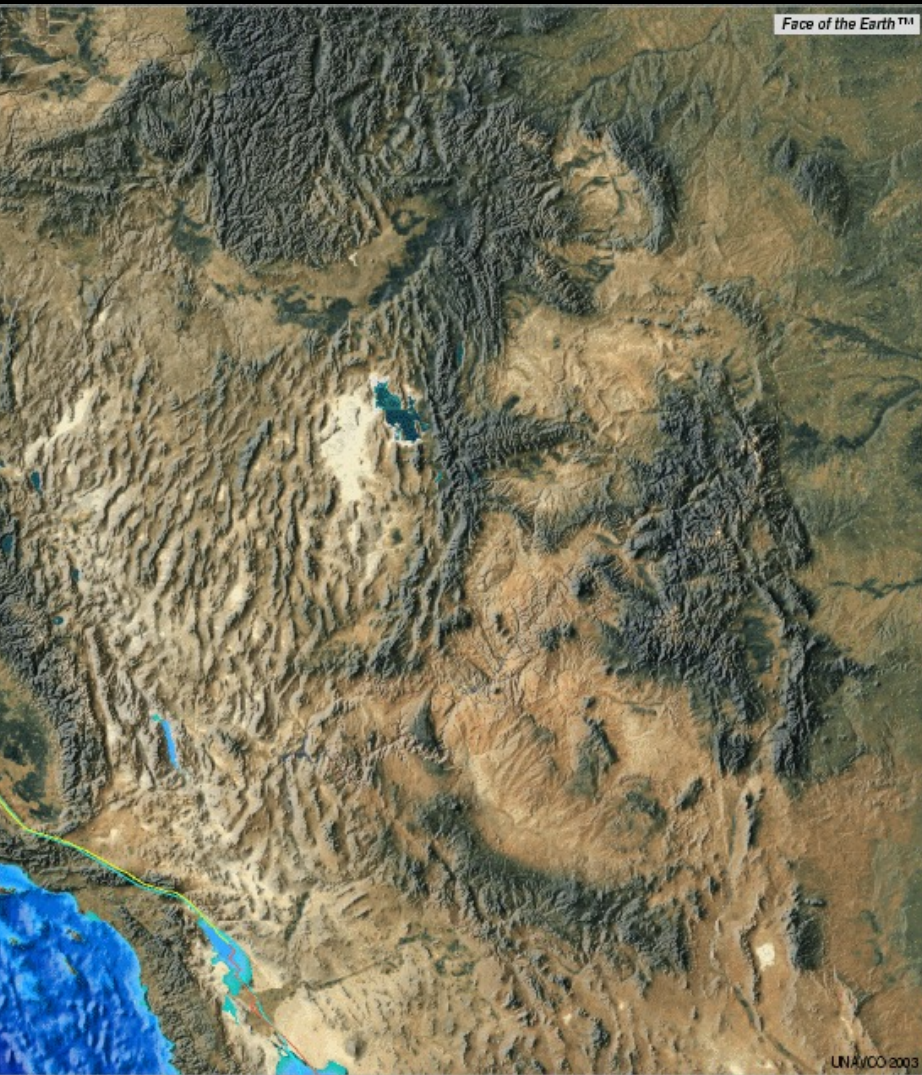
## Why is the Basin and Range interesting?

- You can see the Earth's crust stretching.
- It's formation is related to the San Andreas Fault in California
- The Rio Grande Rift is related to the Basin and Range province.

# Basin and Range



# Basin and Range

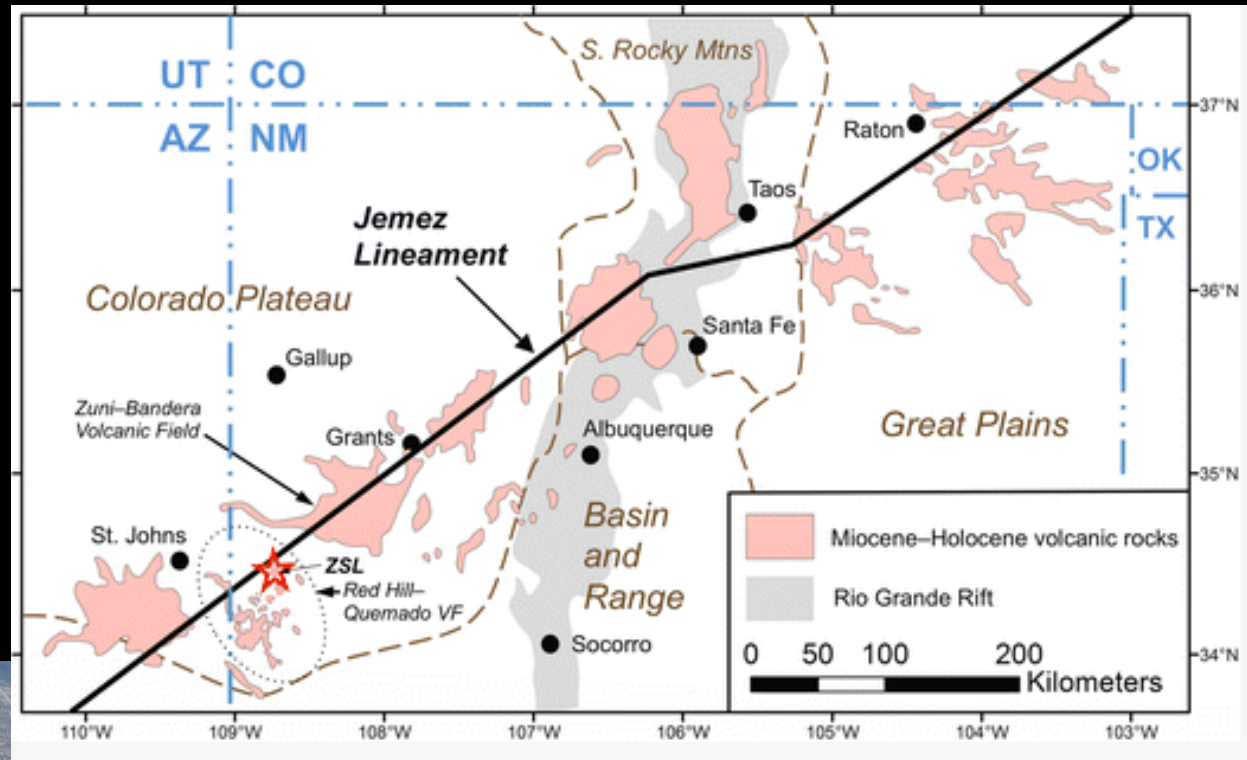


Nps.gov

# Why are Volcanic Lineaments interesting?

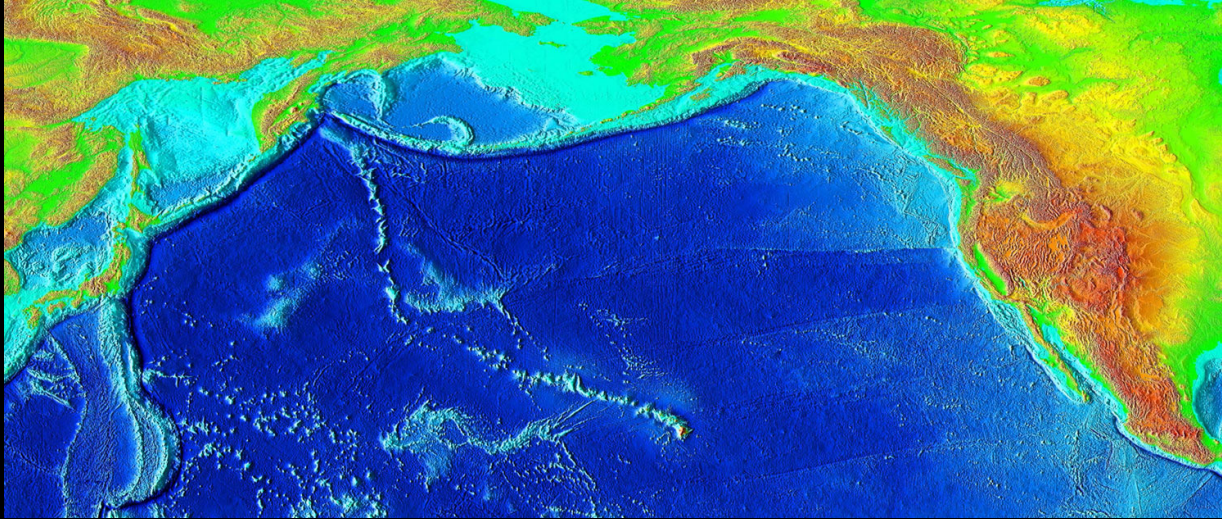
- They tell us something about how the Earth's crust moves and evolves.
- They tell us about something that is happening within or beneath the Earth's crust.

# Volcanic Lineaments

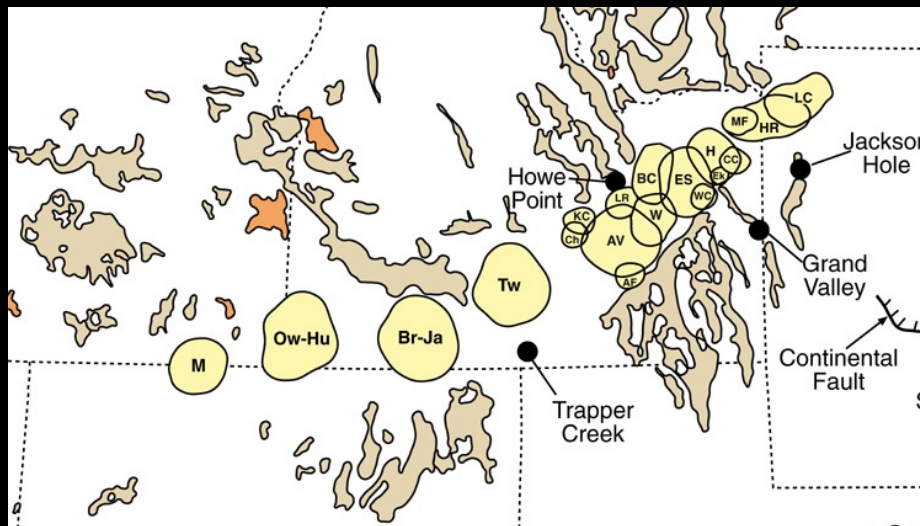


# Other Famous Volcanic Lineaments

Hawaii



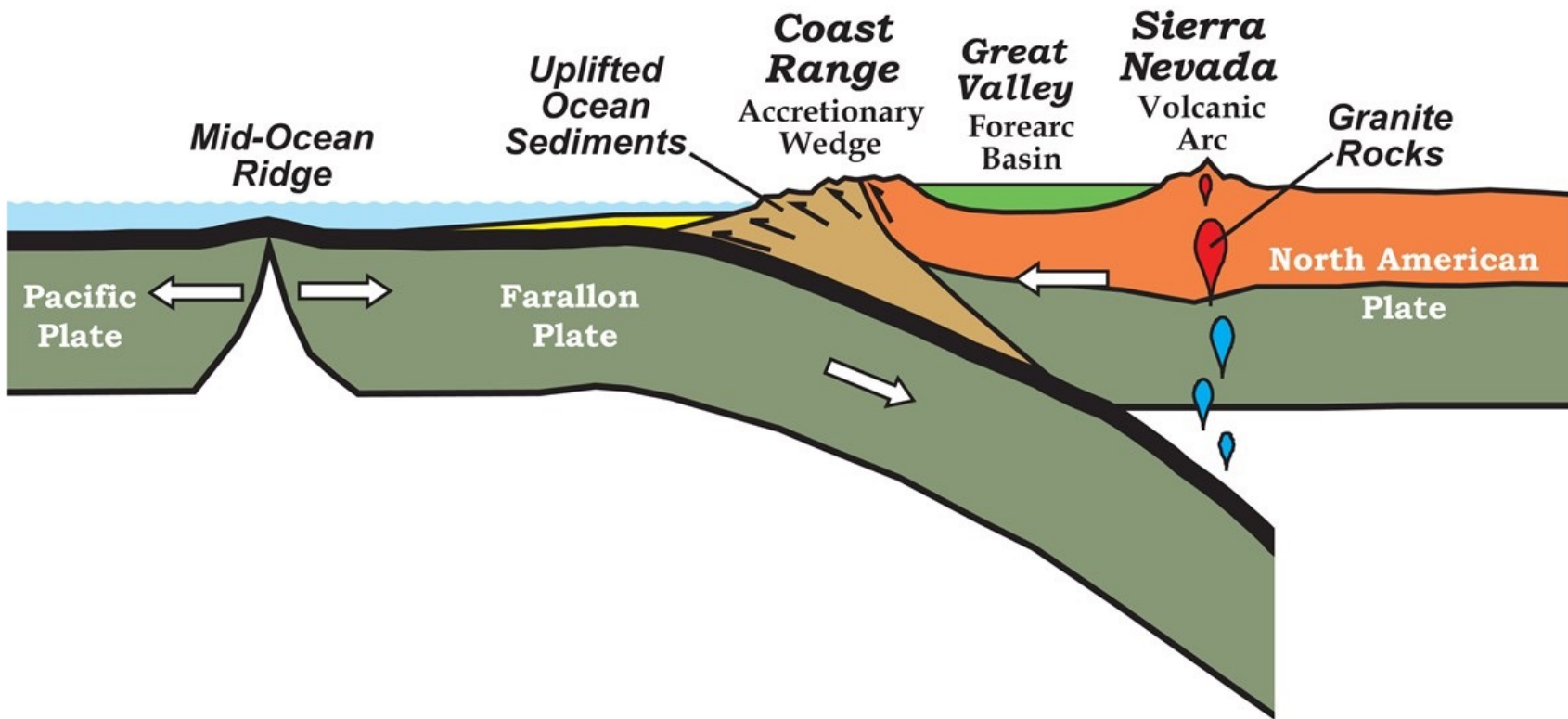
Yellowstone

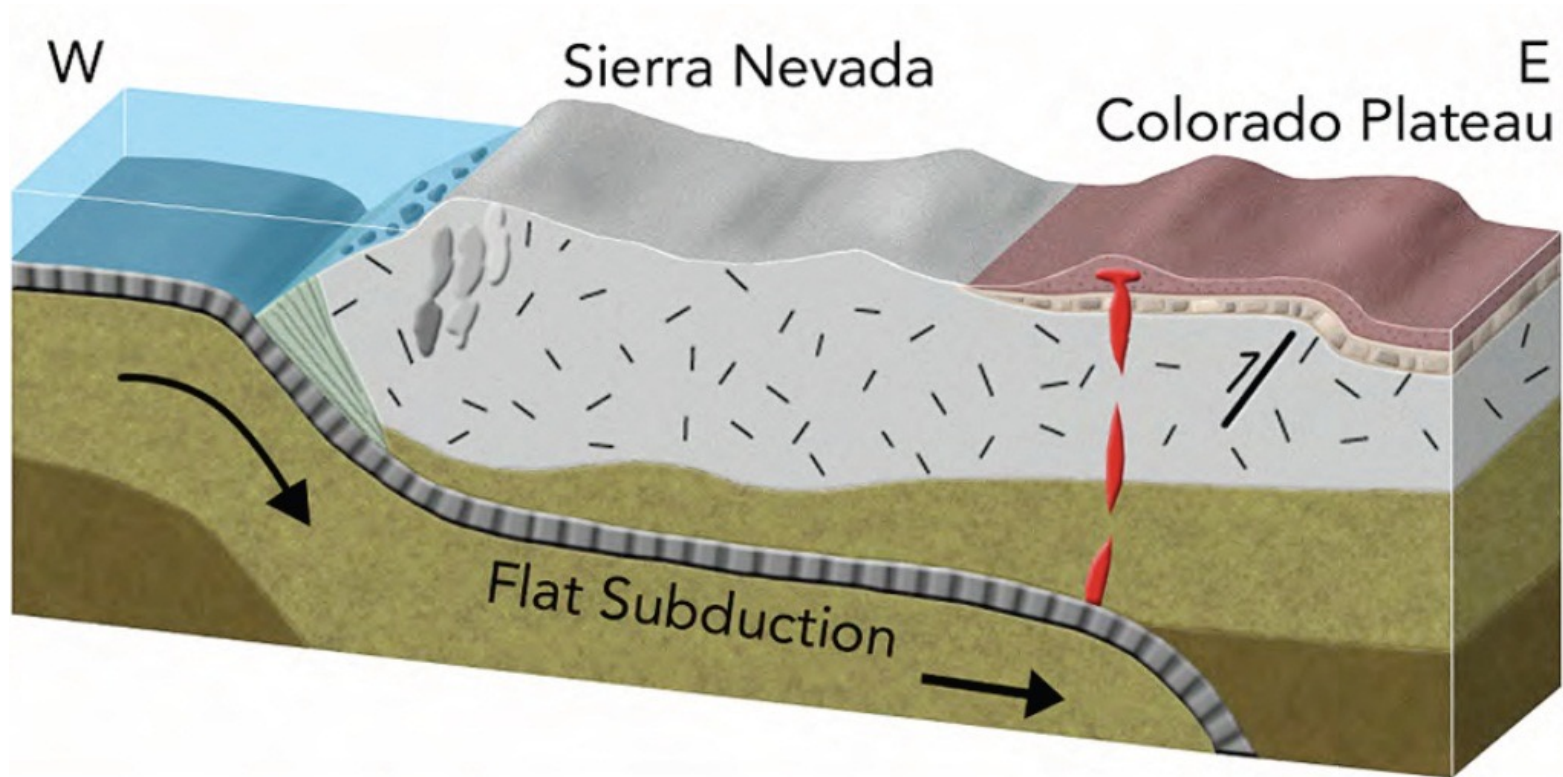


Mark Anders

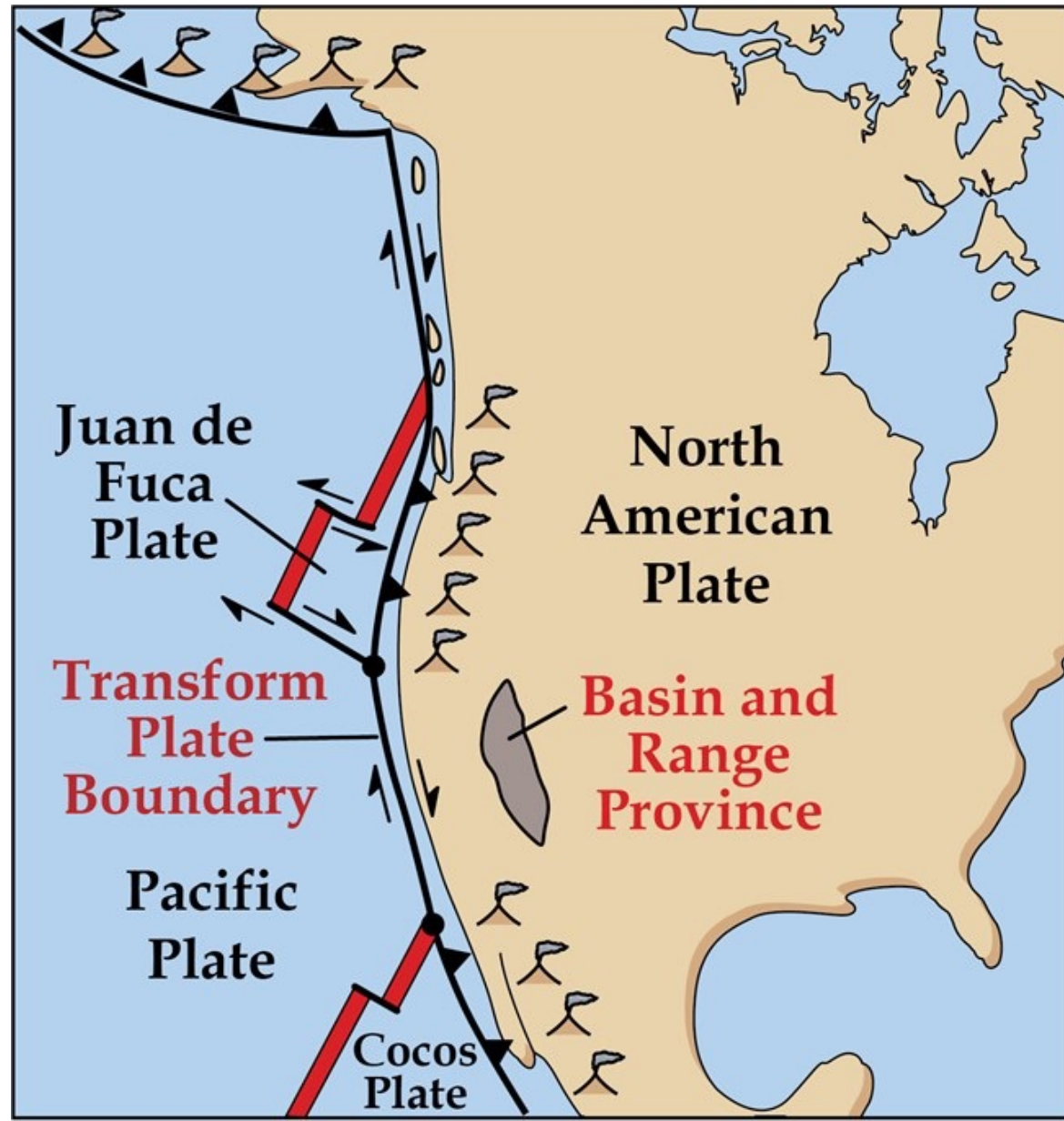
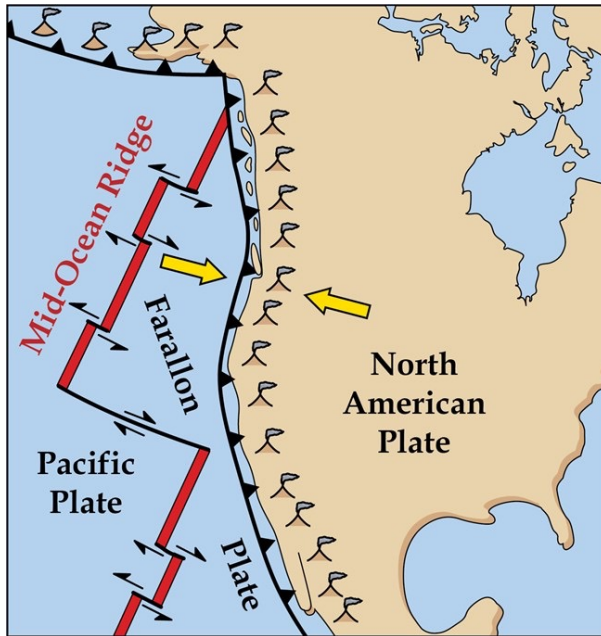
Why do we have the Rio Grande Rift, Basin and Range, and all the Volcanos?



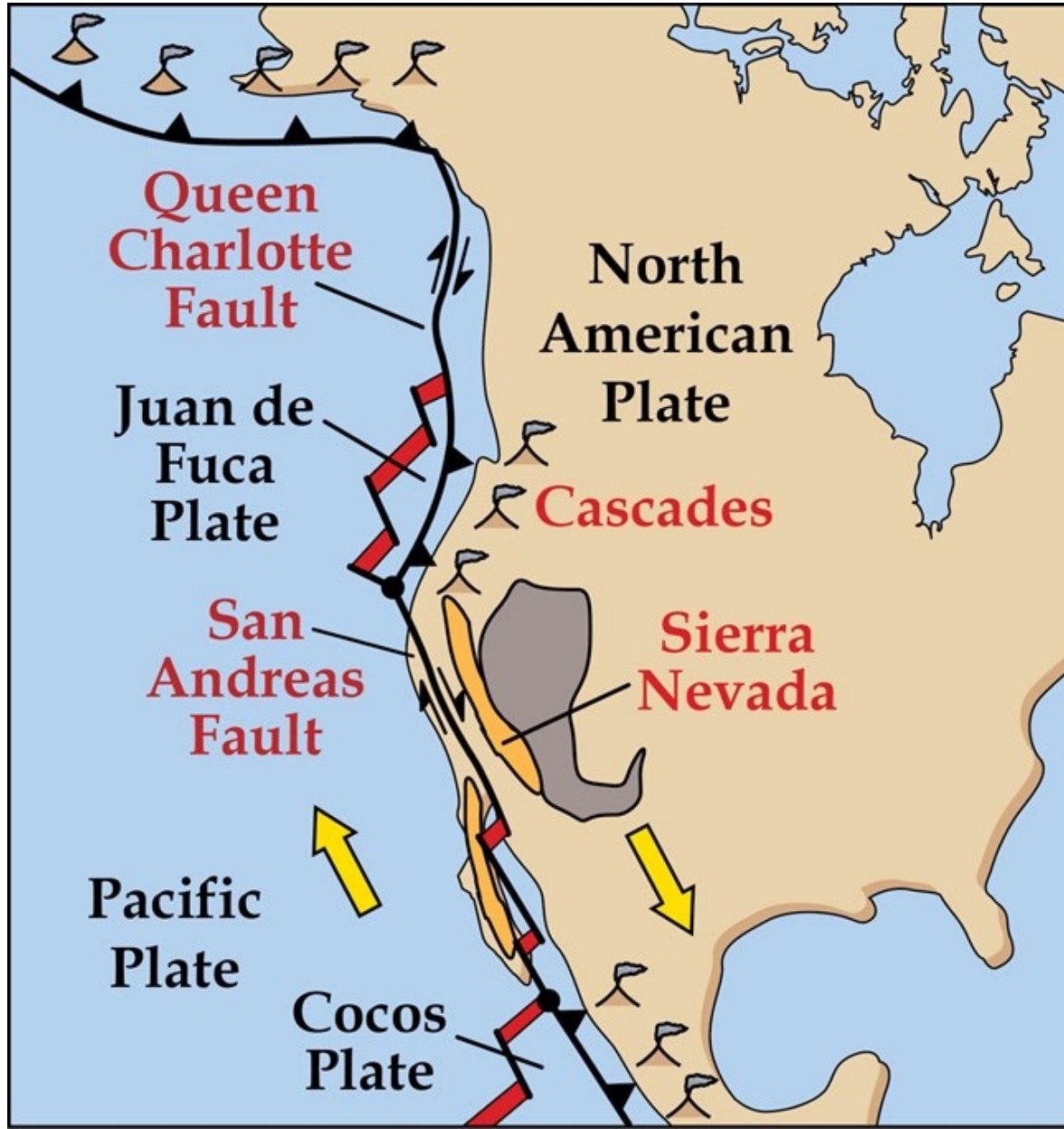




# 20 Million Years Ago

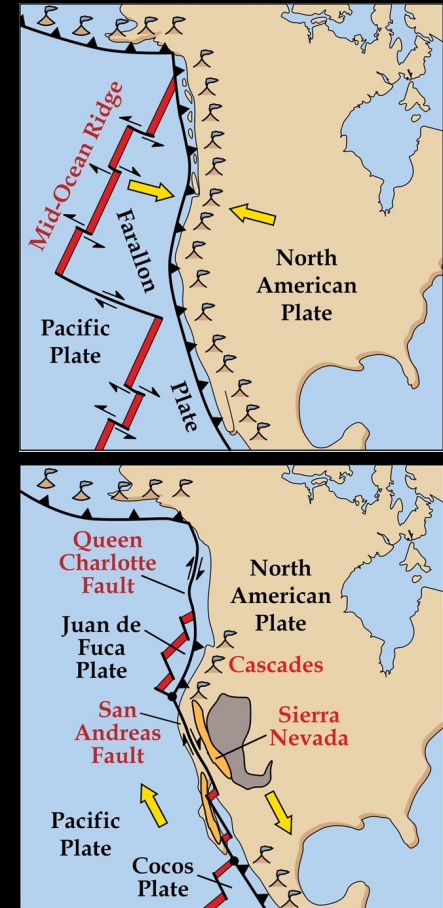


# Today



# Why do we have the Rio Grande Rift, Basin and Range, and all the Volcanos?

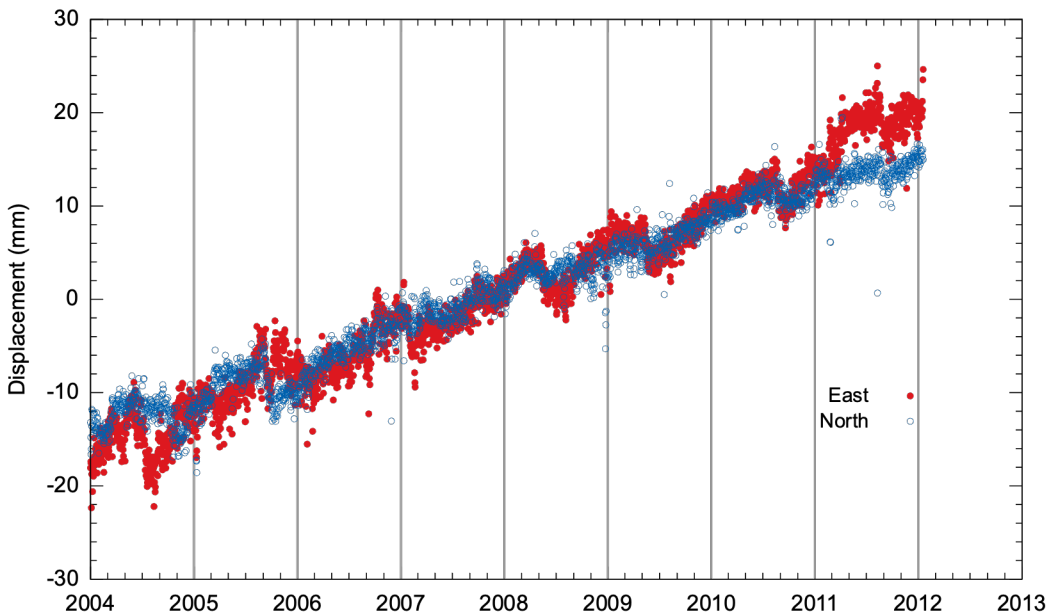
1. The Colorado Plateau and surrounding areas are compressed and uplifted during the mountain building episode associated with the Rocky Mountains, due to the convergent plate boundary.
2. The mid-ocean ridge is consumed at the plate boundary, changing the plate-boundary forces.
3. The region that was uplifted begins to relax and extend.
4. The Rio Grande Rift is a small wedge of the Basin and Range spreading province on the eastern edge of the stable Colorado Plateau.
5. Due to rifting, the earth's crust within Rio Grande Rift is very thin compared to normal continental crust, resulting hot rocks closer to the surface, and volcanos.



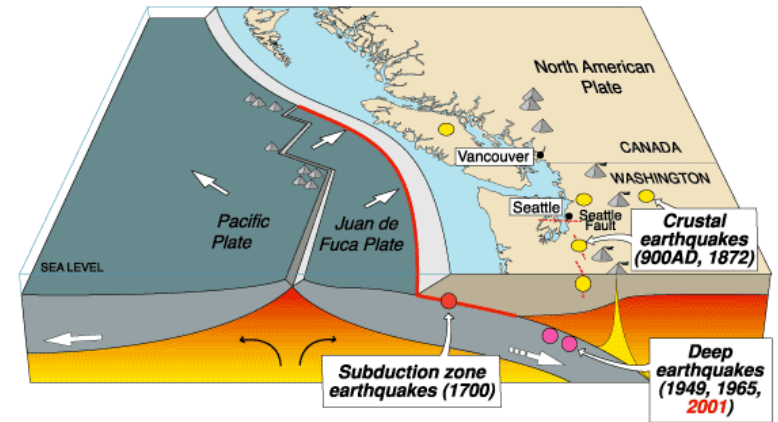
# Bonus slide: episodic tremor and slip in British Columbia



Displacement of Albert Head Station, Victoria, British Columbia (ALBH)



## Cascadia earthquake sources



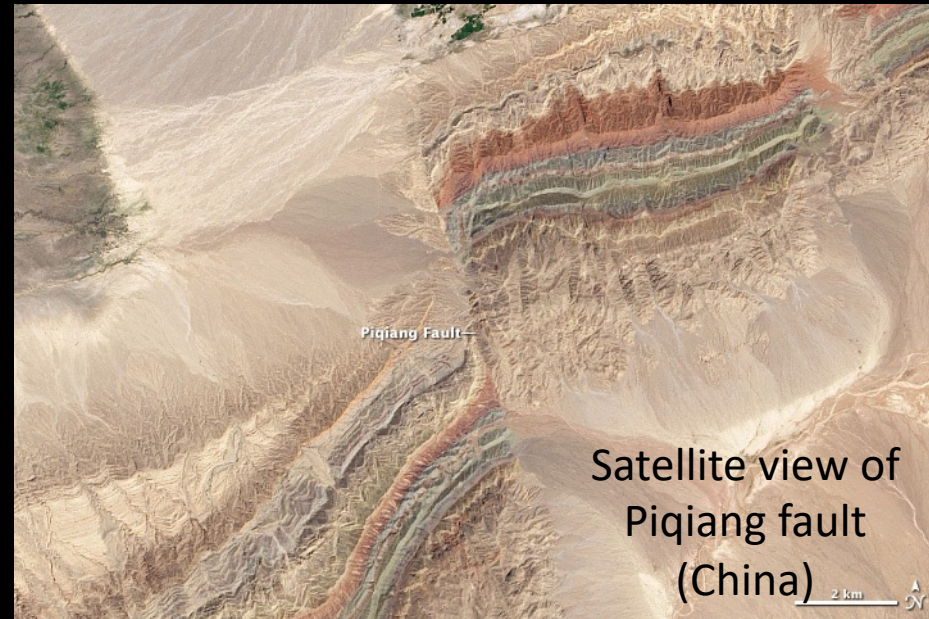
Source	Affected area	Max. Size	Recurrence
● Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
● Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
● Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

# How do earthquakes get triggered, questions I get, and other interesting earthquake stuff.

## 1957 rupture, Gobi-Altai fault, Mongolia

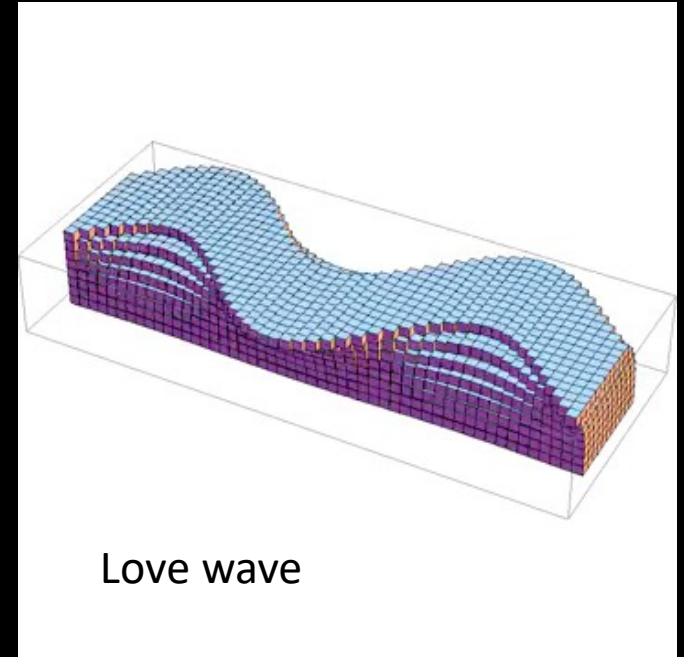
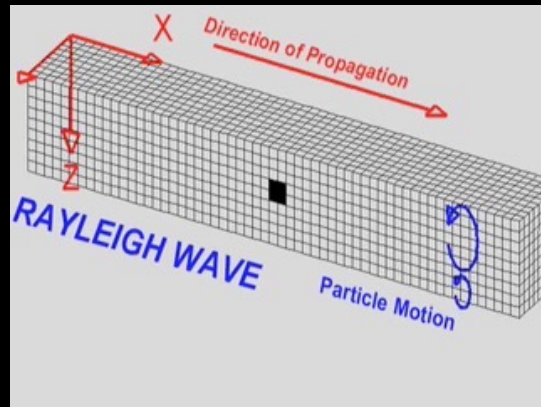
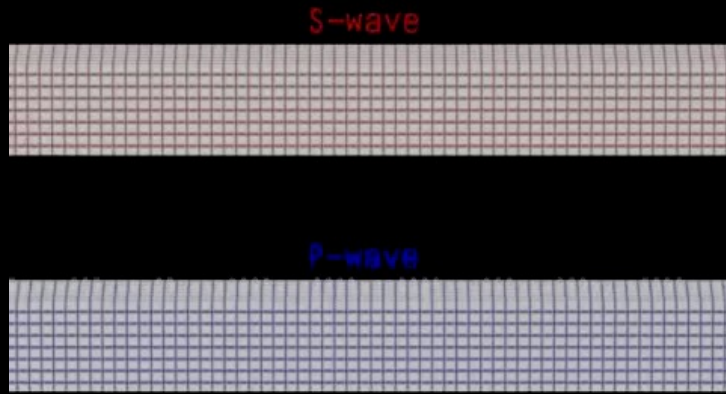


S. Marco (pers. Comm. Via Y. Ben Zion)



Satellite view of  
Piqiang fault  
(China)

# Seismic waves created by earthquakes



# How do earthquakes get triggered?

(The term “triggered earthquake” does not have a universally accepted definition.)

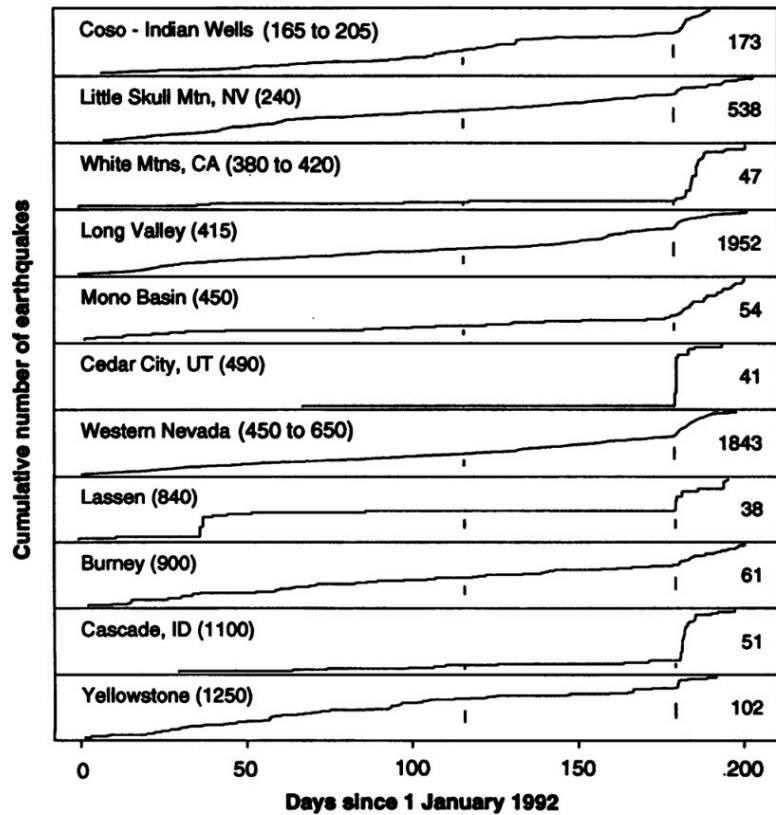
1. Static stress changes in the earth due to a nearby earthquake.
2. Strong seismic waves from a nearby or distant earthquake.
3. Stress changes in the earth due to something other than an earthquake
  1. Tidal forces (Solid Earth and Ocean)
  2. Changes in load (such as filling or draining a reservoir)
  3. Changes in fluid pressure (natural or anthropogenic)
    - a) Water or Brine
    - b) Oil
    - c) Gas
    - d) Carbon Dioxide
  4. Movement of magma in the subsurface

# Static stress changes in the earth due to a nearby earthquake.

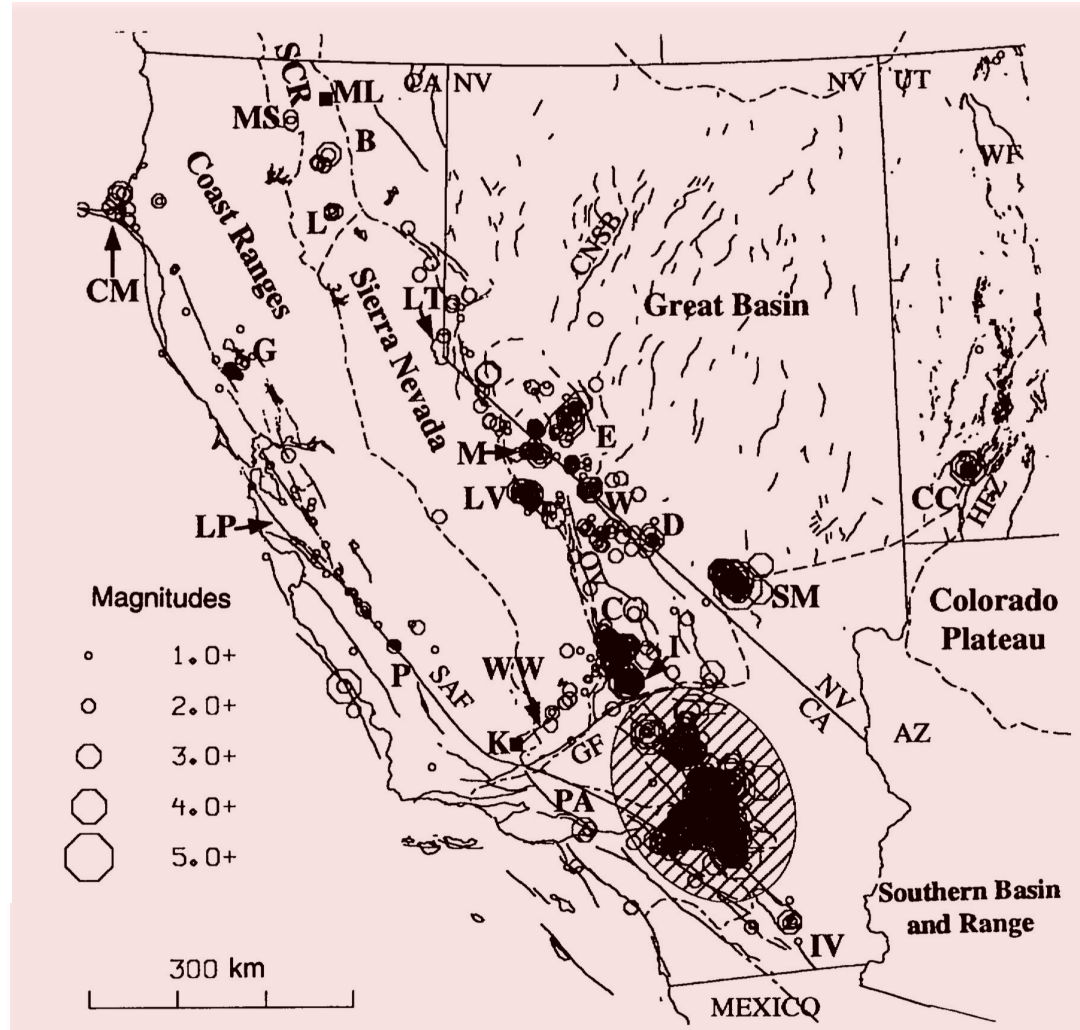


# Strong seismic waves from a nearby or distant earthquake.

Triggering due to the 1992 M7.2 Landers earthquake

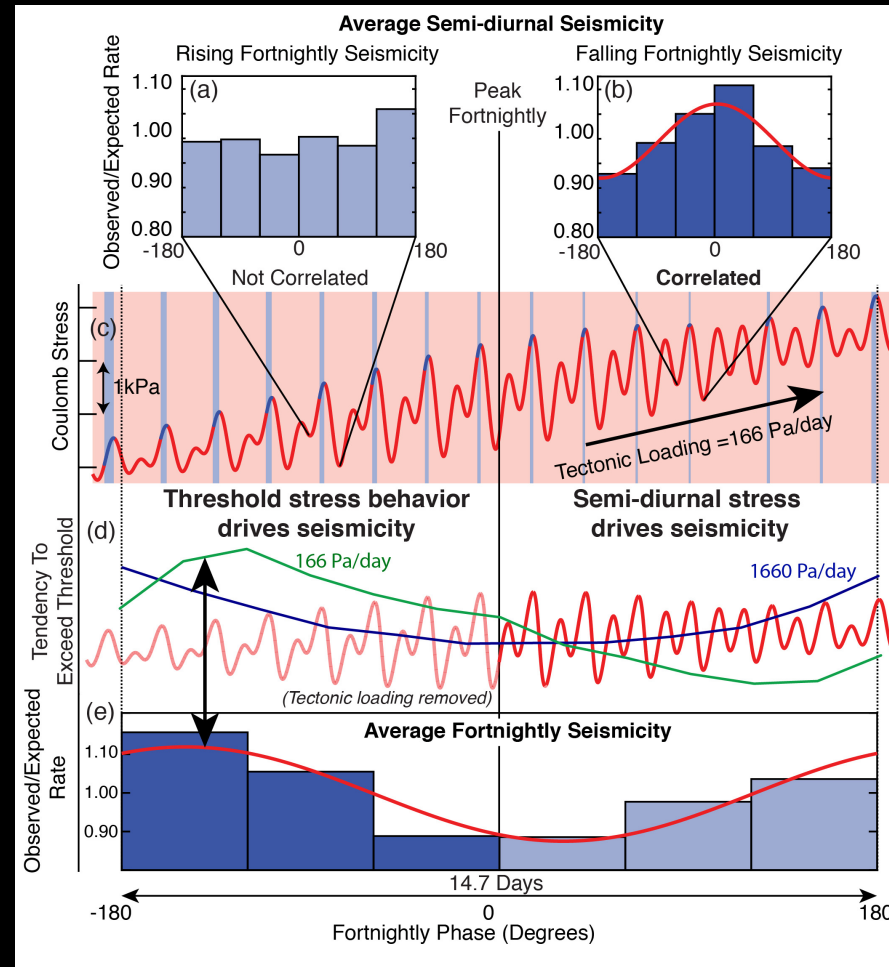
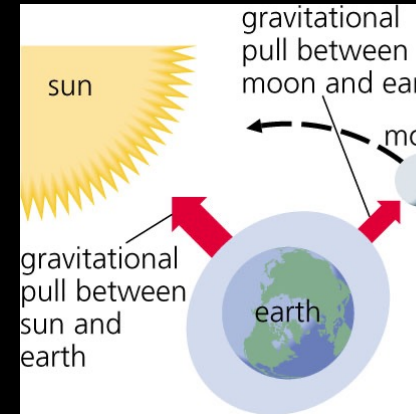
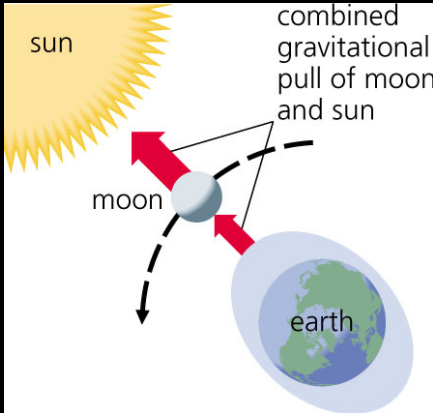


SCIENCE • VOL. 260 • 11 JUNE 1993

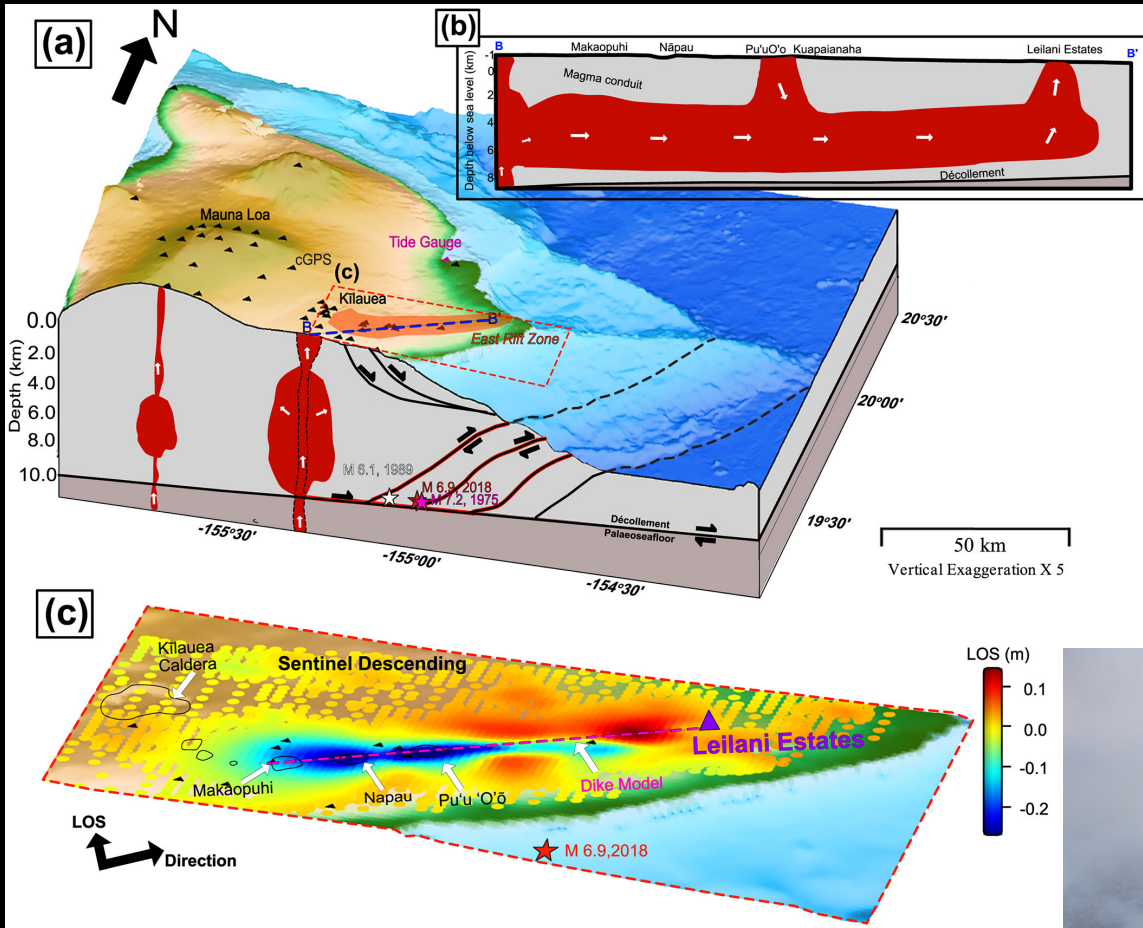


Hill et al., Science (1993)

# Earthquakes triggered by solid-earth tides

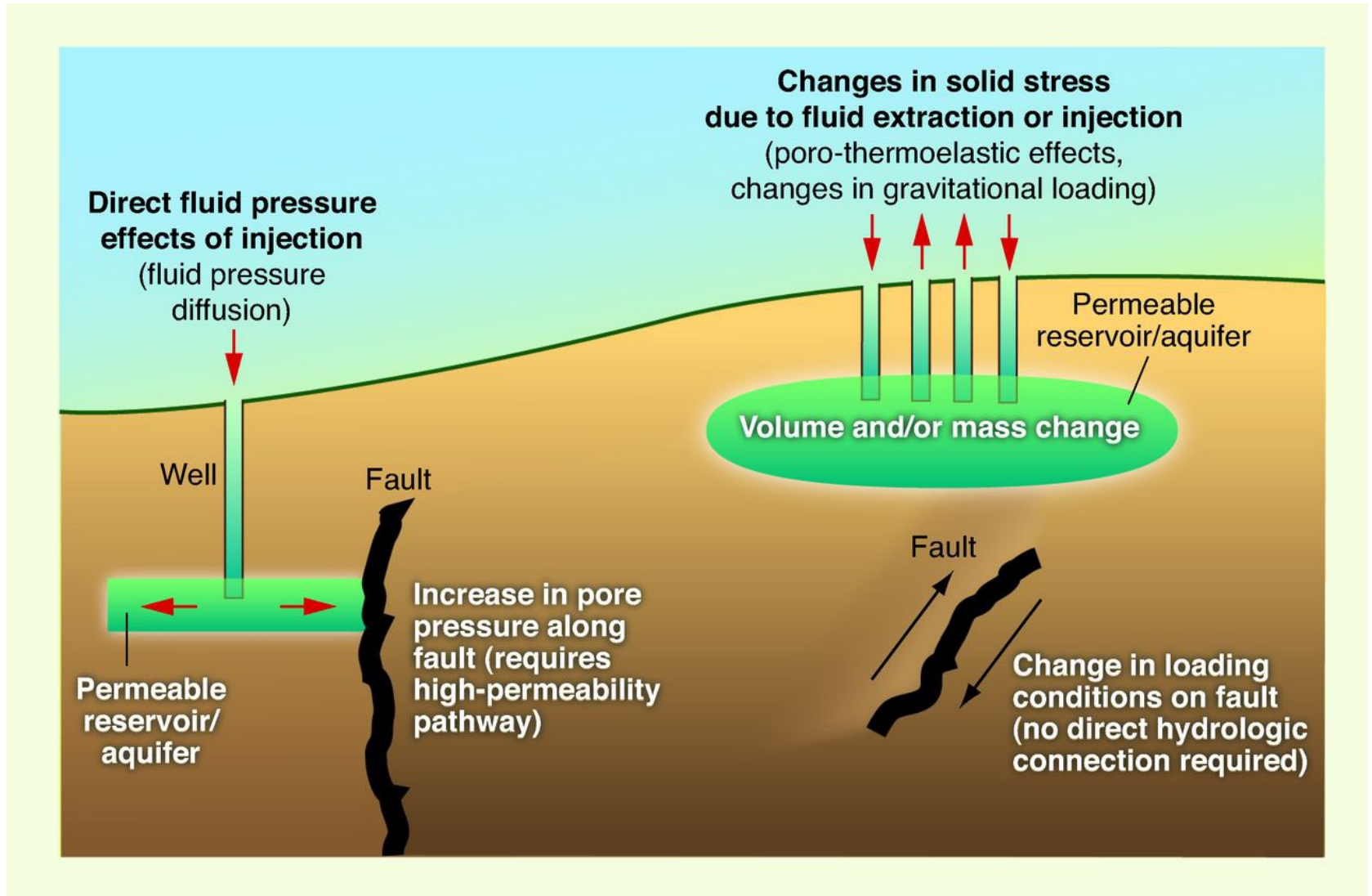


# Earthquakes triggered by movement of magma



Chen et al [2019]

# Earthquakes triggered by changes in load or fluid pressure



Some questions I get when I tell someone that I am a geophysicist.

(long pause)

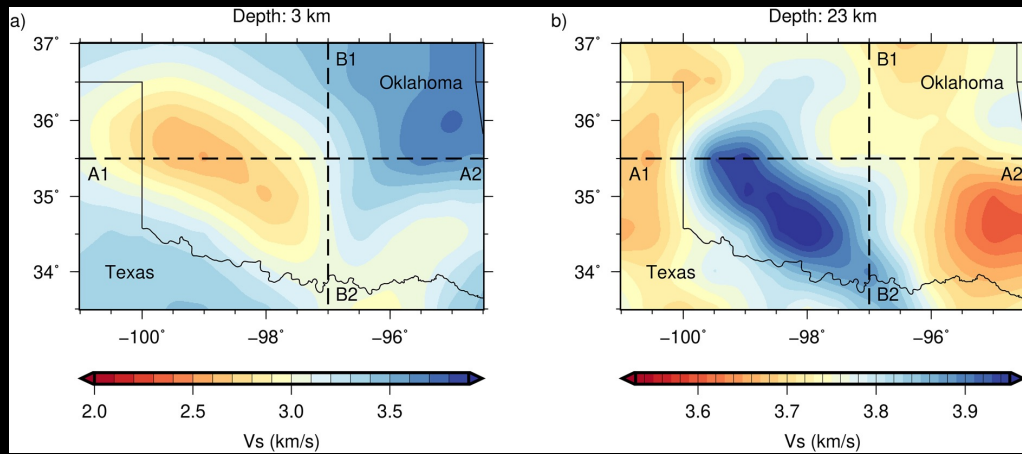
What's that?

Me: I study earthquakes.

Oh, cool.

# Other applications for seismology besides studying earthquakes.

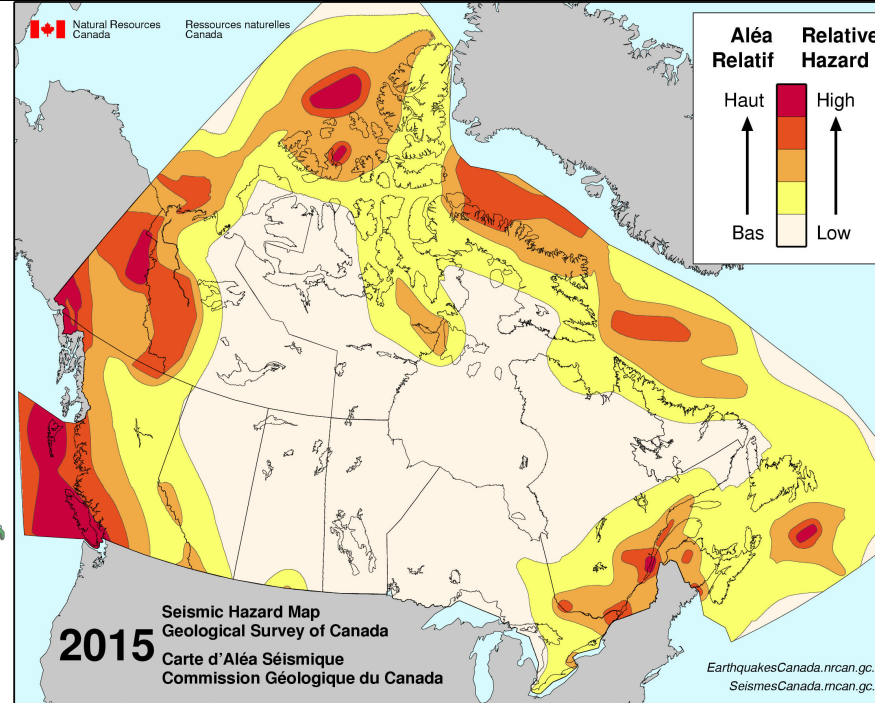
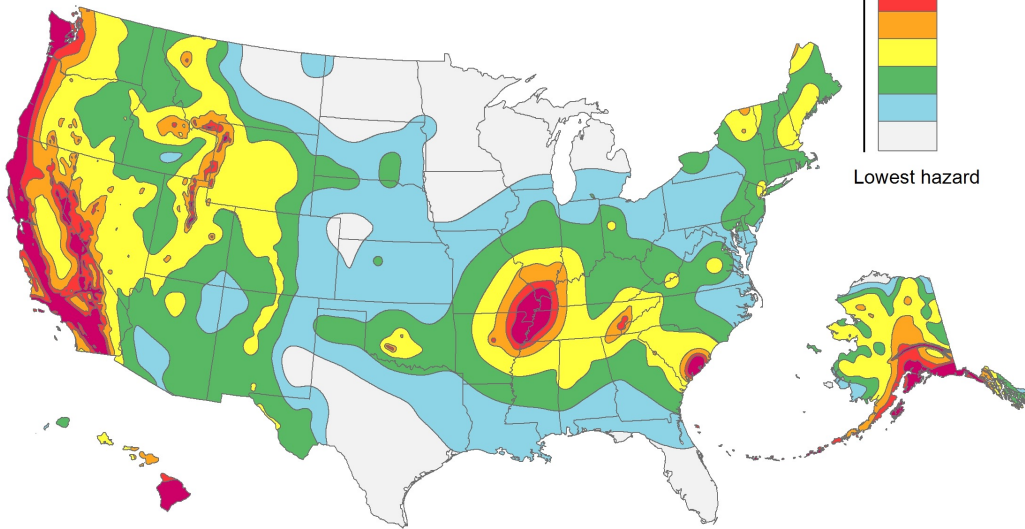
Tomography (imaging, kind of like a medical sonogram).



Chai et al [2019]

# Other applications for seismology besides studying earthquakes.

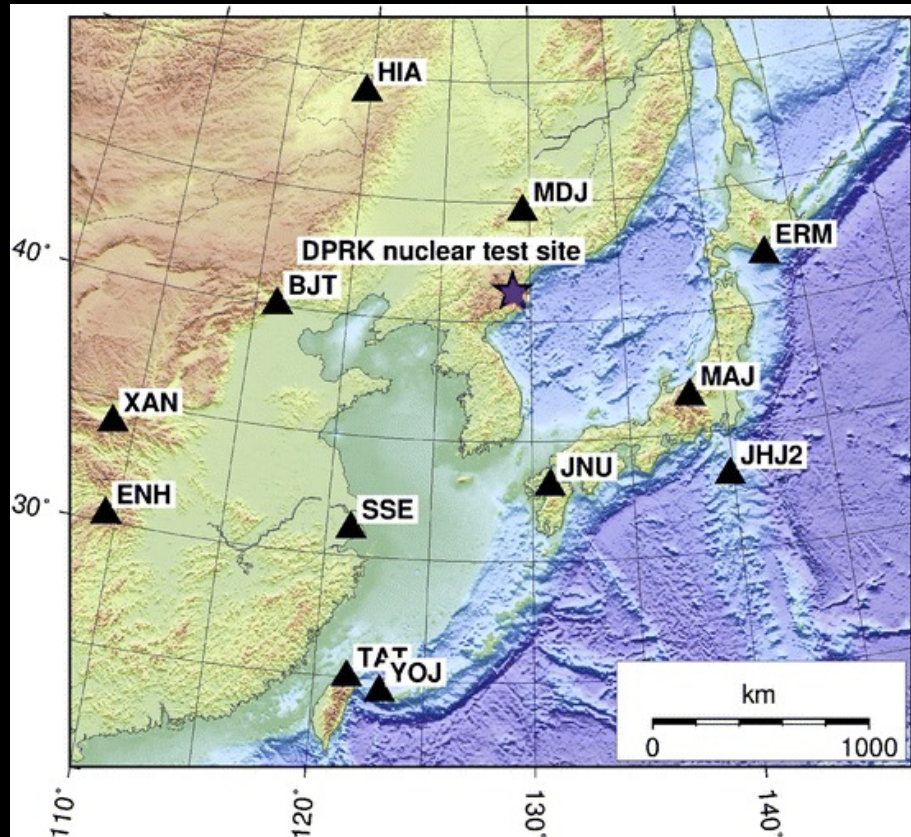
## Seismic Hazards



These maps refer to the probability of experiencing a particular level of ground motion over a particular length of time. They are not predicting any particular earthquake.

# Other applications for seismology besides studying earthquakes.

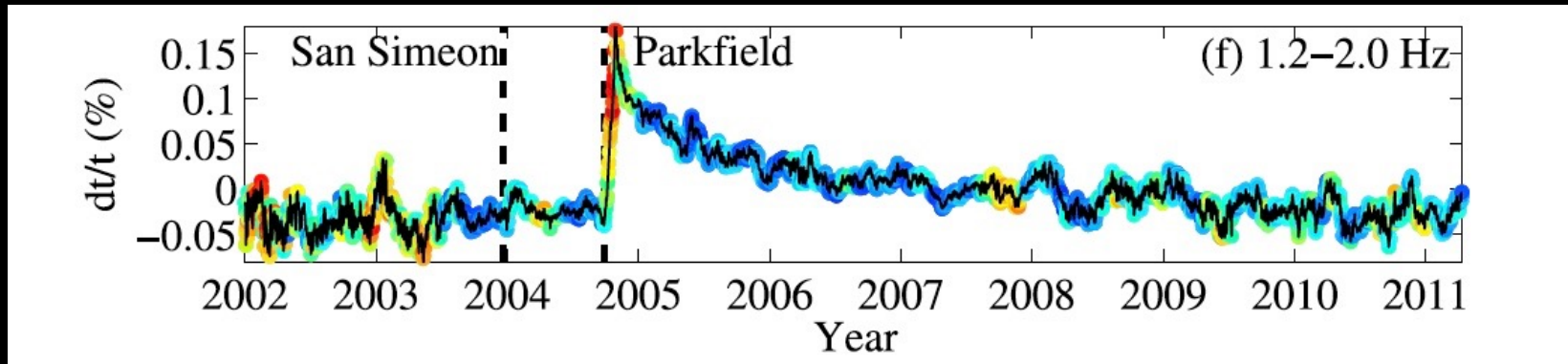
## Monitoring Nuclear Tests



Barth [2014]

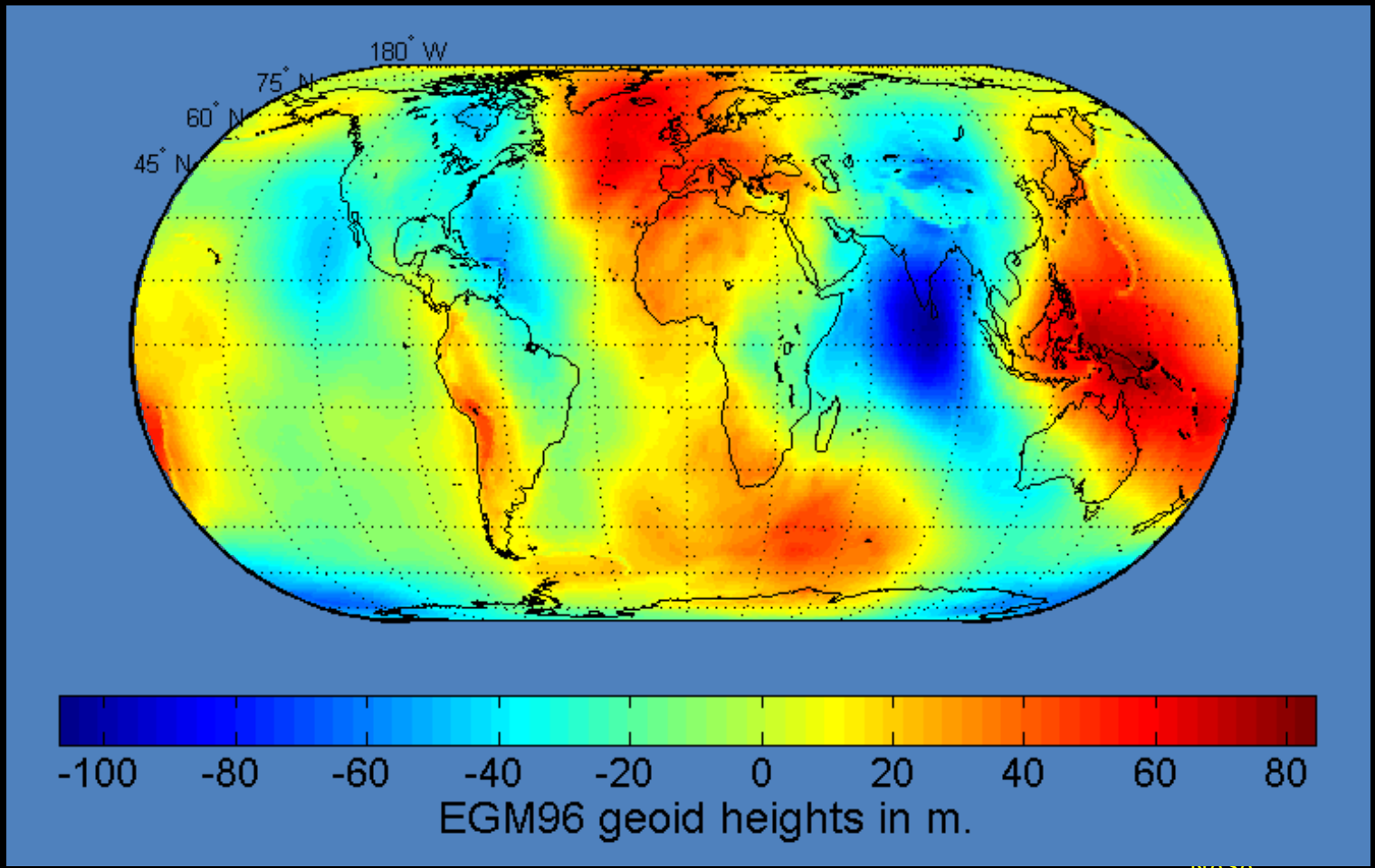
# Other applications for seismology besides studying earthquakes.

Measuring subsurface damage to rocks from large earthquakes

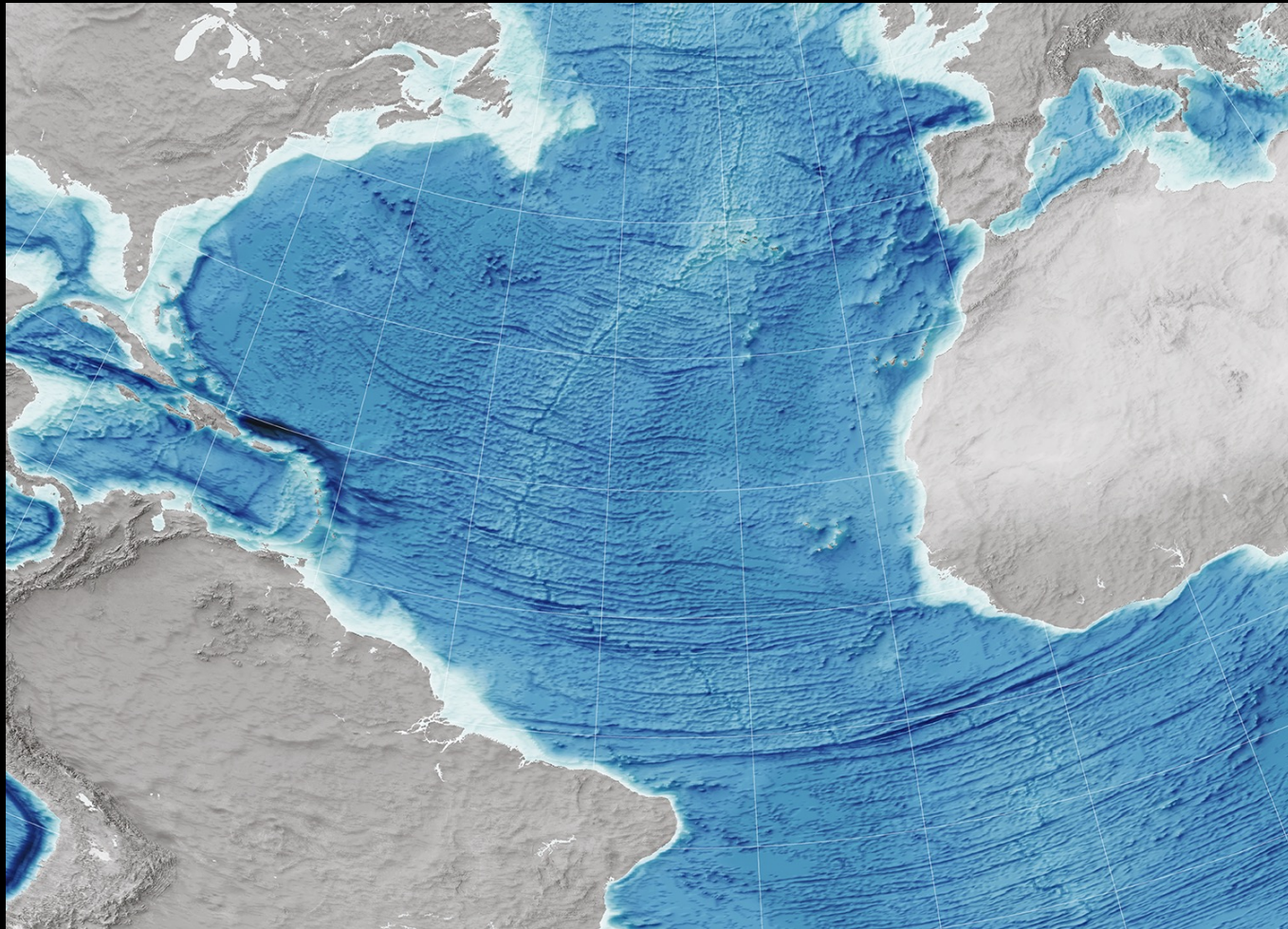


Wu et al [2016]

# Gravity Measurements



# How do we map the floor of entire oceans?



NASA

# Will we ever be able to predict earthquakes?

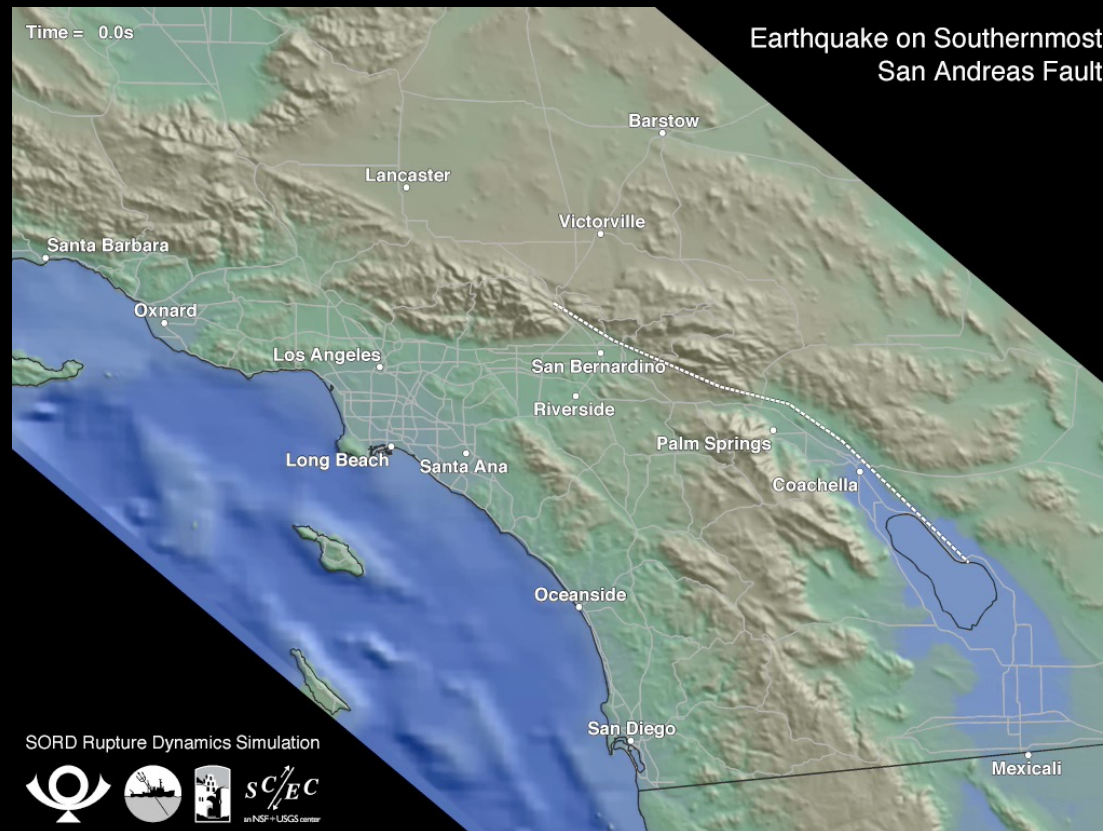
In geophysics, we define earthquake prediction as predicting the time, location, *and* magnitude of an earthquake within a precision that allows society to prepare for the specific event. By this definition, we will most likely never be able to predict earthquakes.

“There will be a magnitude 3 earthquake in California tomorrow.”

“There will be a magnitude 8 or greater earthquake off the coast of Oregon, Washington, or British Columbia sometime in the next 500 years that will produce a destructive tsunami.”

# When is the big one going to happen?

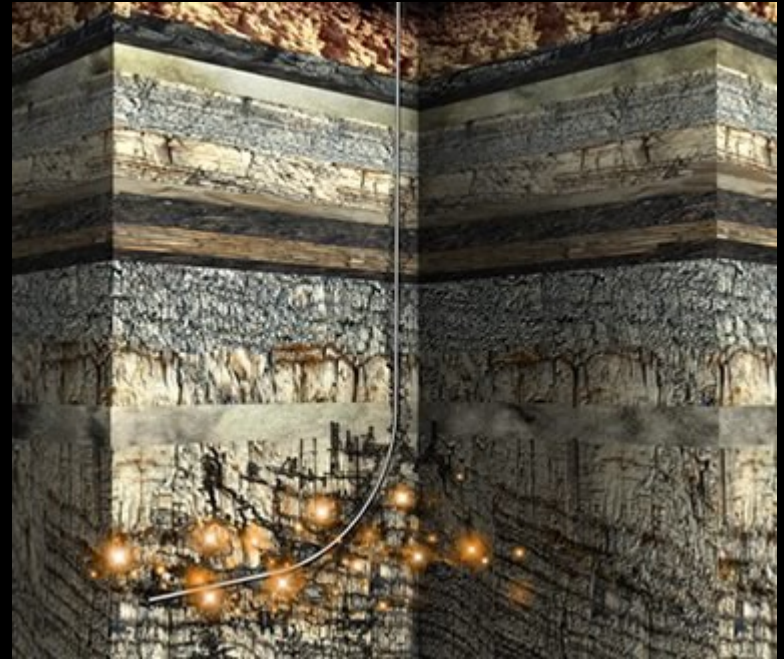
Who knows? If you live in an earthquake-prone region, you should be prepared. There are some relatively simple things you can do to make sure your house has some resiliency. Having a stash of non-perishable food and water is a good idea.



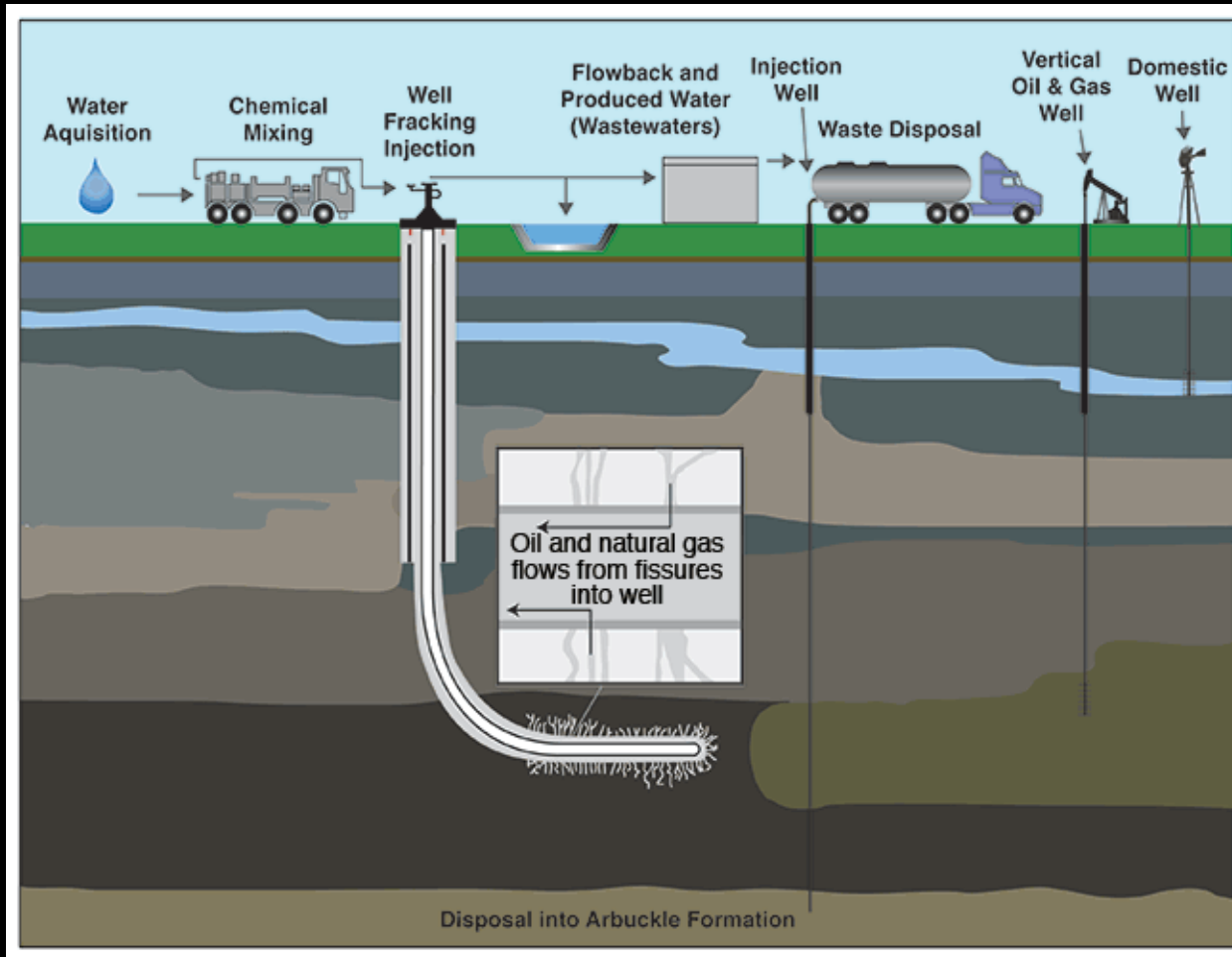
How are tsunamis triggered?



# Does Fracking cause earthquakes?

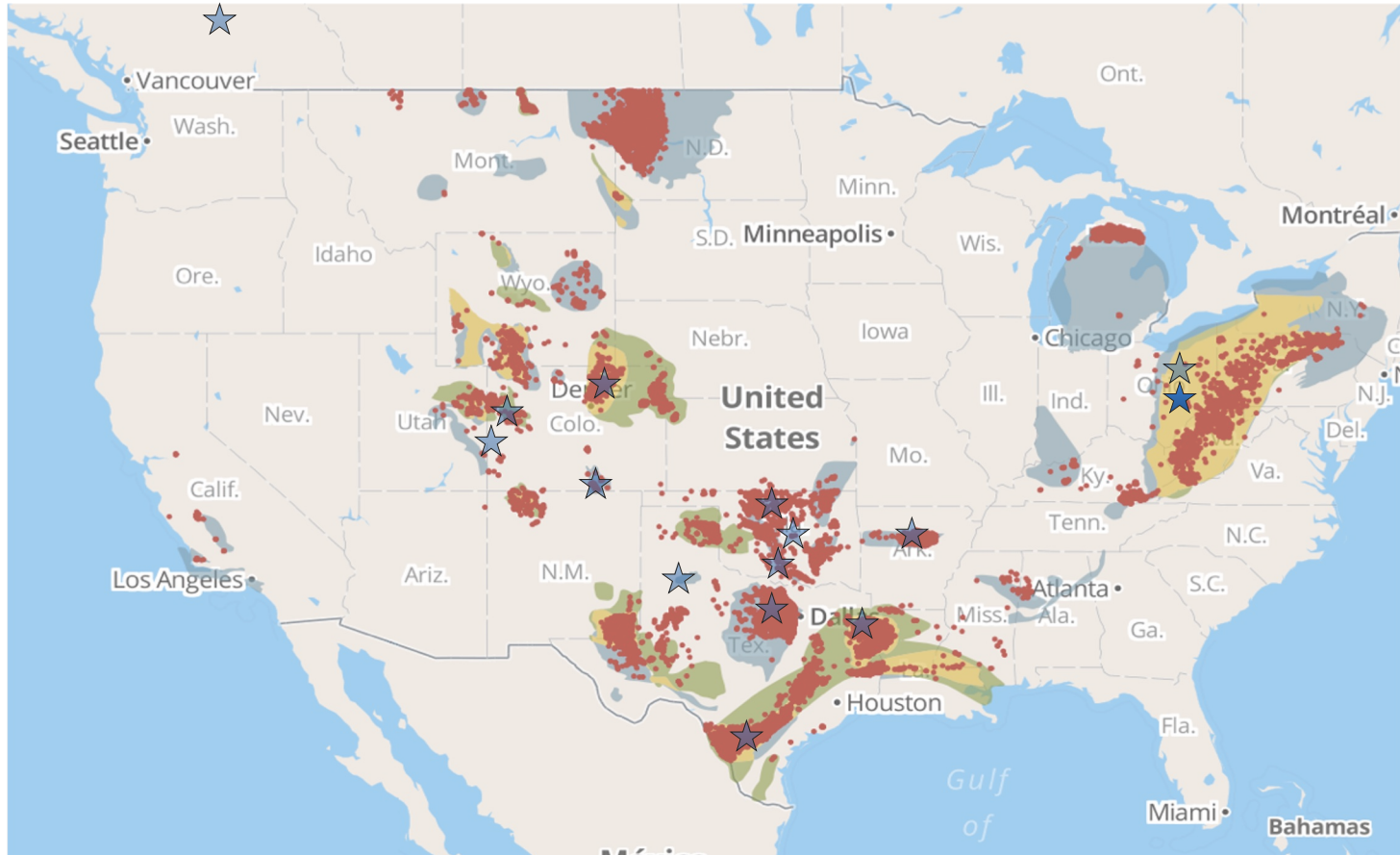


# Does Fracking cause earthquakes?



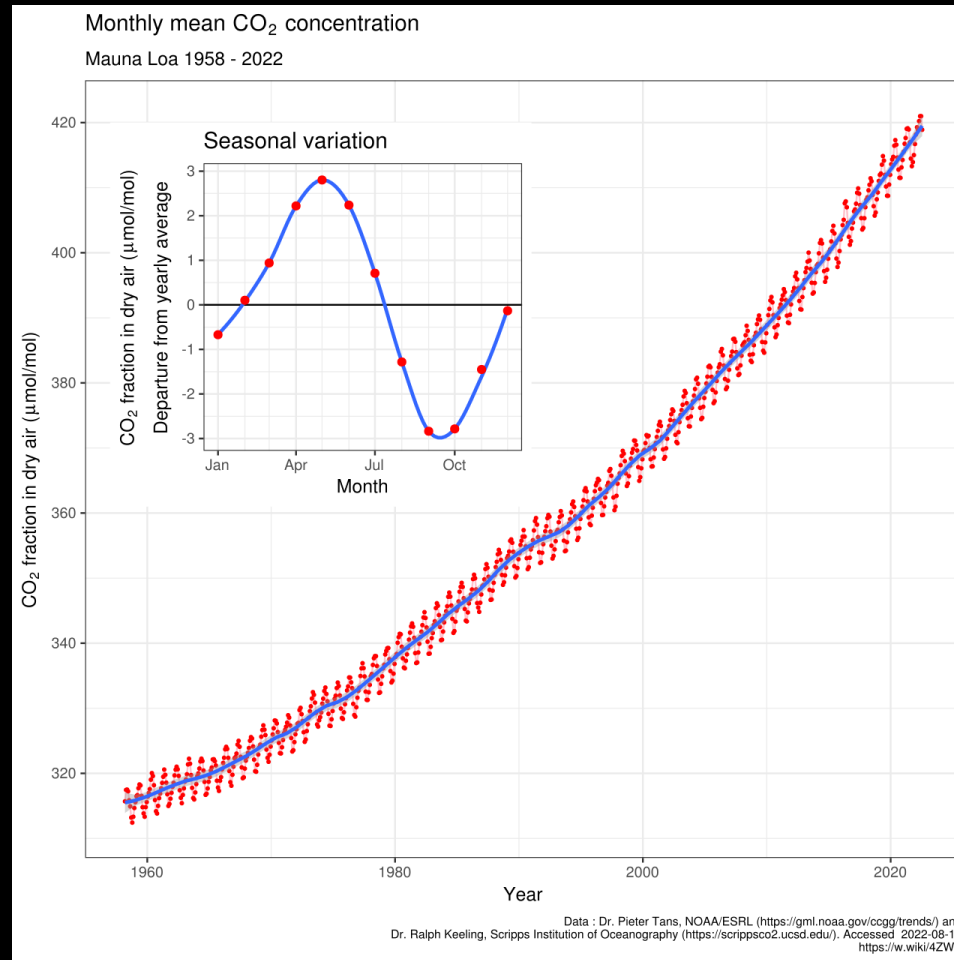
Generally, no. It is the wastewater injections that induce earthquakes. There is some risk of contaminating fresh water aquifers with any hydrocarbon exploration and fracking uses a lot of water.

# Places where earthquakes are linked to fluid injections



# Will we ever run out of oil and gas?

We will have a major climate disaster long before we will run out of oil.



# What happened with the Deepwater Horizon and other similar accidents?

Pockets of subsurface fluids, such as brine (water), methane (natural gas), or petroleum can be at very high pressures due to the weight of all the rock above them. If we drill into these pockets, the pressure can be released up the wellbore. If the fluid is flammable, then it will often ignite.



One more cool video from the 2011 Japan earthquake



2011 M9.0 Japan earthquake (as experienced in Mukuhari, Japan)

What are your questions?