Earthquakes and Tsunamis


Nisqually Quake – Washington State, Feb. 2001
6.8 Mag.
Photo: www.missouri.edu
Have you felt the earth move? What was it like?

How do we know big earthquakes have happened in the past?

Thunderbird and Whale had a terrible fight. Illustration by Jeffrey Veregge

https://www.hakaimagazine.com/features/great-quake-and-great-drowning/

On Vancouver Island, the Nuu-chah-nulth people told tales of mountain dwarves inviting a person to dance around their drum. When the person accidentally kicked the drum—depicted in the illustration above by Nuu-chah-nulth artist Tim Paul—he got earthquake foot and his steps set off vast tremors. Image courtesy of the Royal BC Museum and Archives

https://www.hakaimagazine.com/features/great-quake-and-great-drowning/

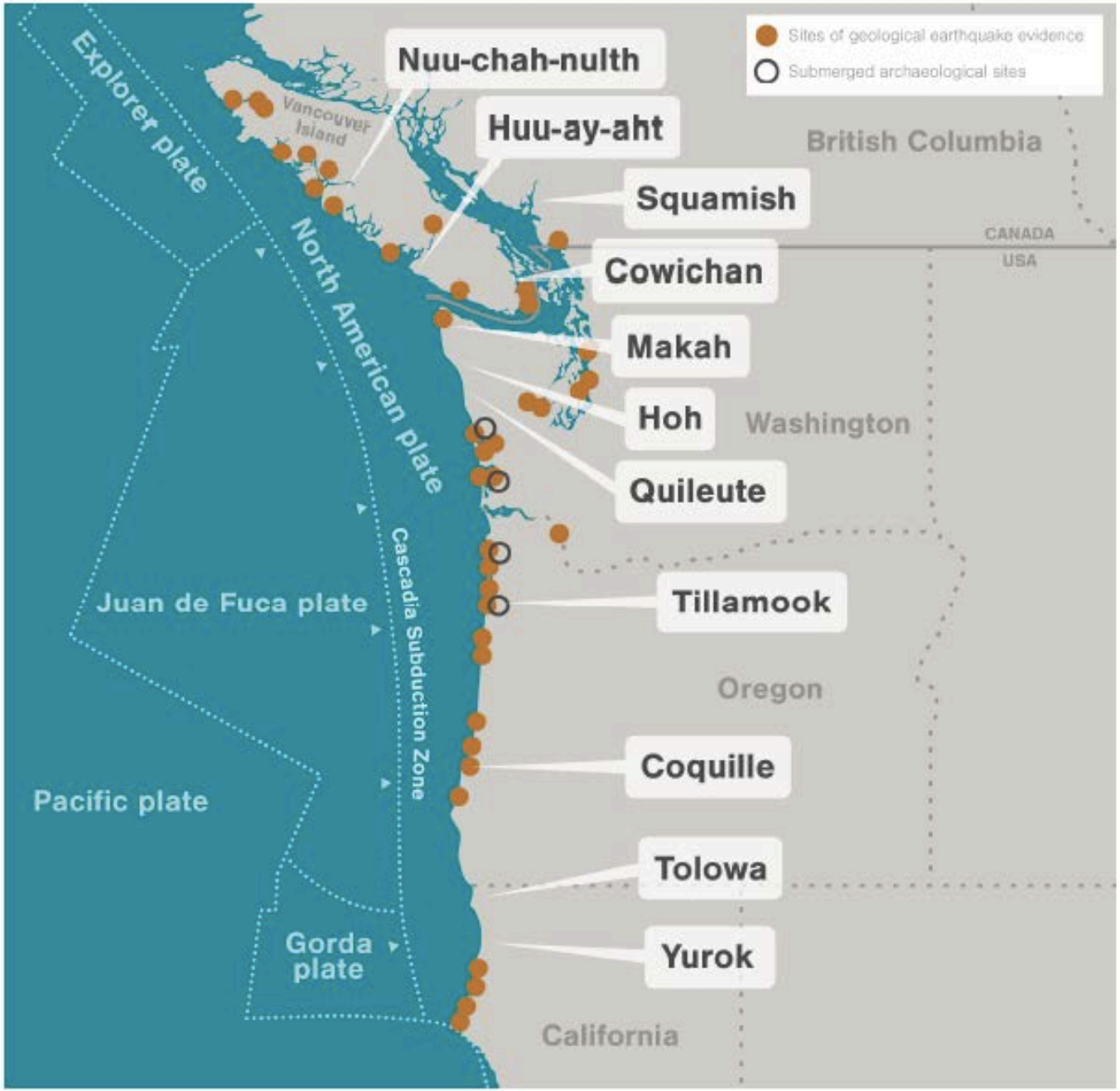
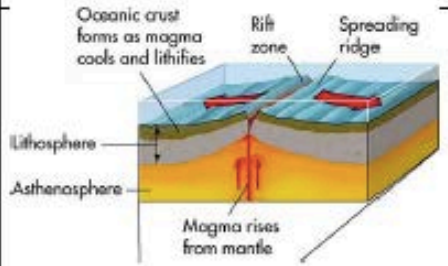
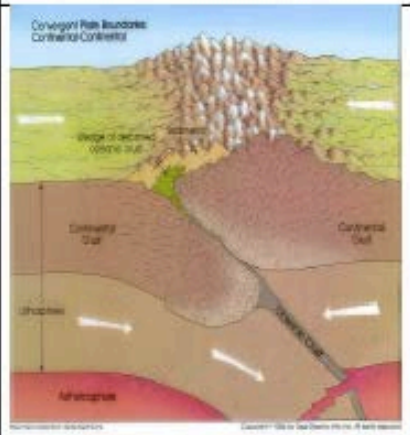
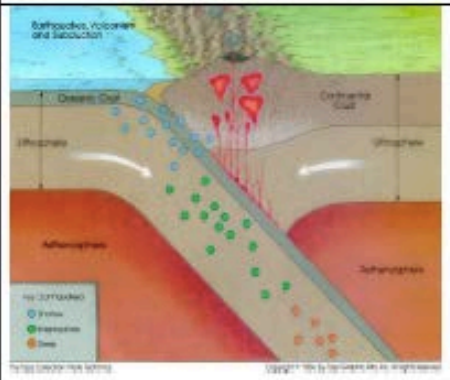


Illustration by Mark Garrison

Figure 9. Tsunami sand (labeled s) overlying an eroded peaty soil (so) in a pit dug near Tofino, British Columbia (photo by J. J. Clague). The tsunami was triggered by a large earthquake about 300 years ago. The sand is overlain by intertidal mud (m) which grades upward into peat (p) of the present-day marsh. The smallest divisions on the stadia rod are centimeters.

Why do earthquakes happen and where do they tend to occur?

Take a 2 minutes to think back to **plate tectonics** and imagine some situations that might lead to an earthquake. Draw a diagram….

xPlate Boundary	Diagram	Plate Action	Associated Processes	Associated Features	Examples: Locations
Divergence		Plates are being pushed apart- divergence	Earthquakes Faulting Shield Volcanoes	Vents Oceanic ridges and faults Rift Zone	Mid-Atlantic Ridge (Iceland) East African Rift Valley
Convergence- Collision Continent/Continent		Plates (continental-continental) are being pushed together	Earthquakes Folding Faulting	Fold Mountain Ranges	Himalayas Rockies Alps
Convergence- Subduction Ocean/Continent		Oceanic and continental plates push up against each other-oceanic deeps because of higher density	Composite Volcanoes/Stratovolcanoes/ Andesitic Major Earthquakes Folding and Faulting Volcanism	Active mountain ranges (active volcanoe) Deep oceanic trenches	Japan Cascades Andes Pacific Ring of Fire

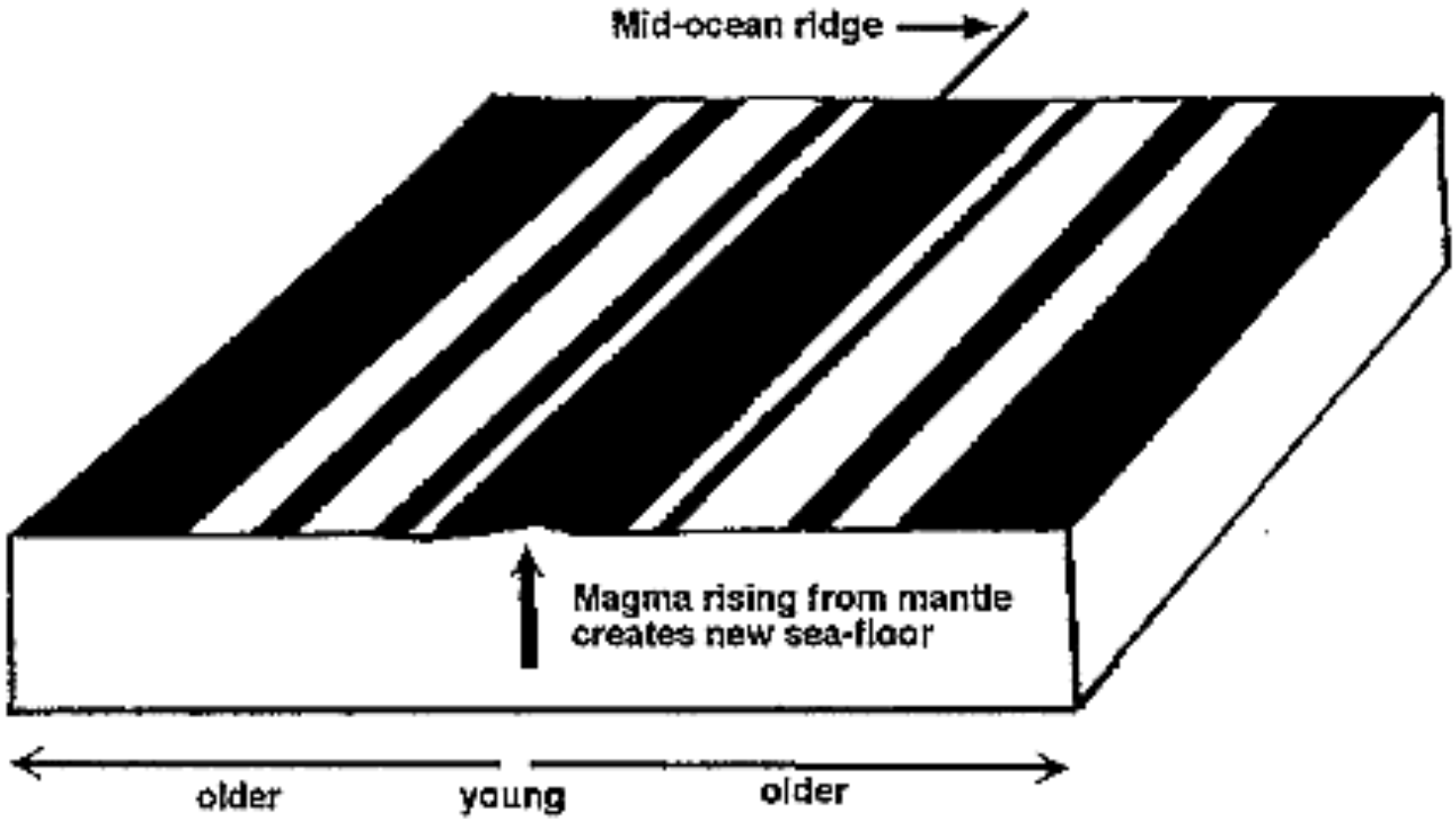


Figure 5. Schematic diagram of magnetic anomalies on the sea-floor. Black represents normal polarity; white is reversed polarity.


2048 × 1536

It's Not My "Fault"!

Many earthquakes occur along faults or fractures in the earth's crust where rocks move relative to one another.

However, there are other causes of earthquakes.

How many can you and your partner brainstorm?

volcano

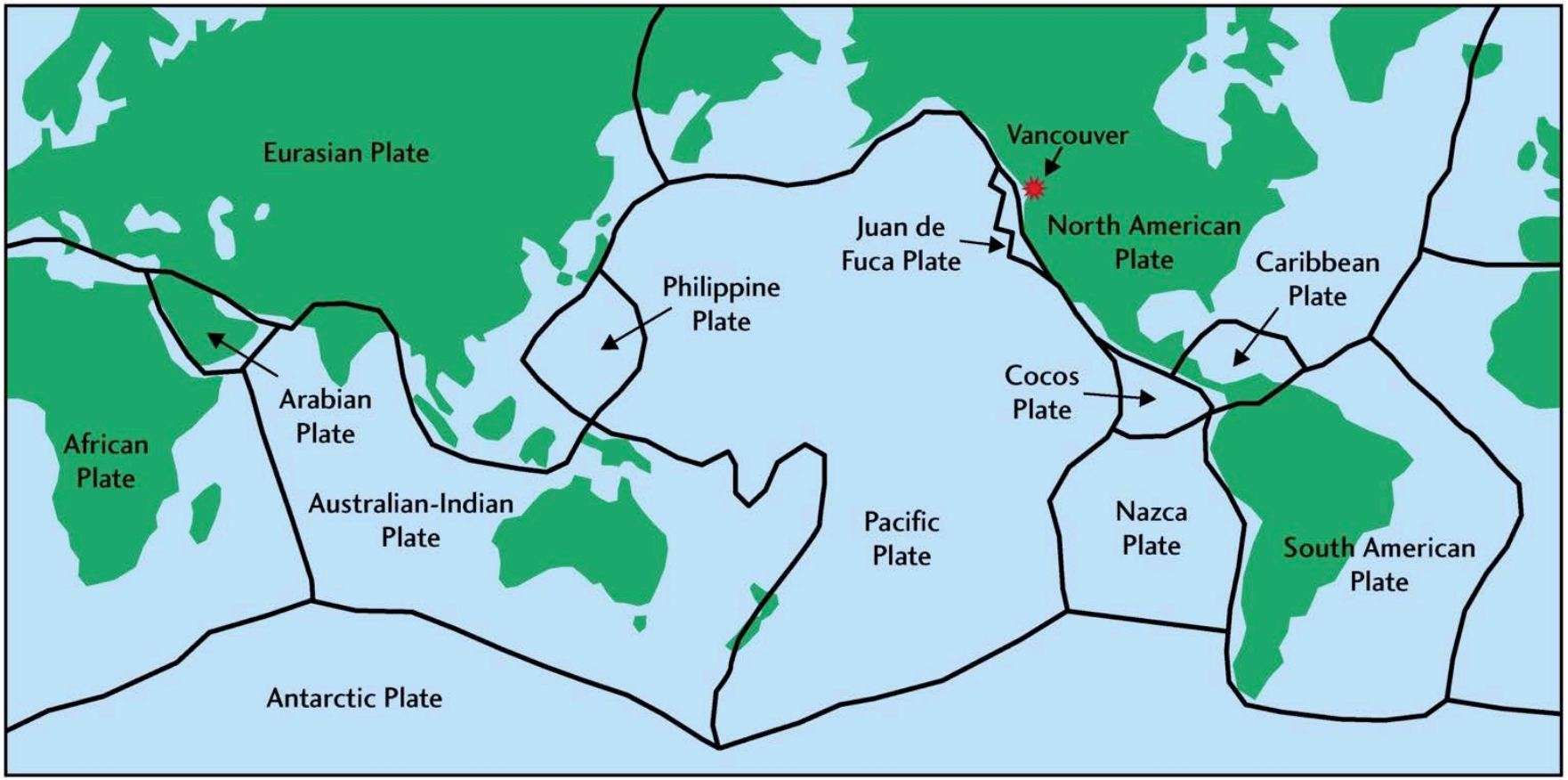
landslide

mining / blasting

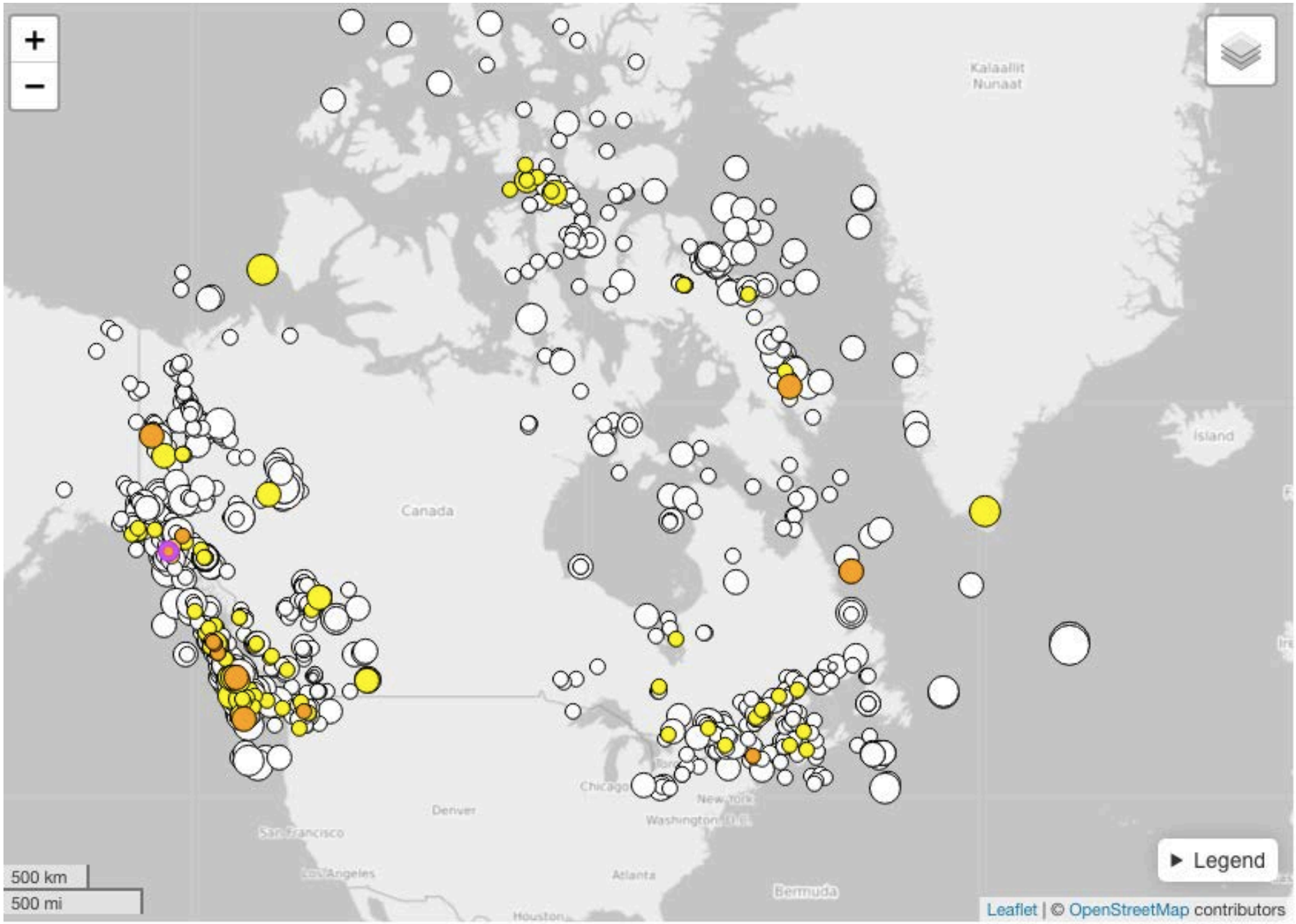
nuclear testing

Fracking

Are you more likely to experience an earthquake in Vancouver or in Toronto? Take a minute and decide with your partner

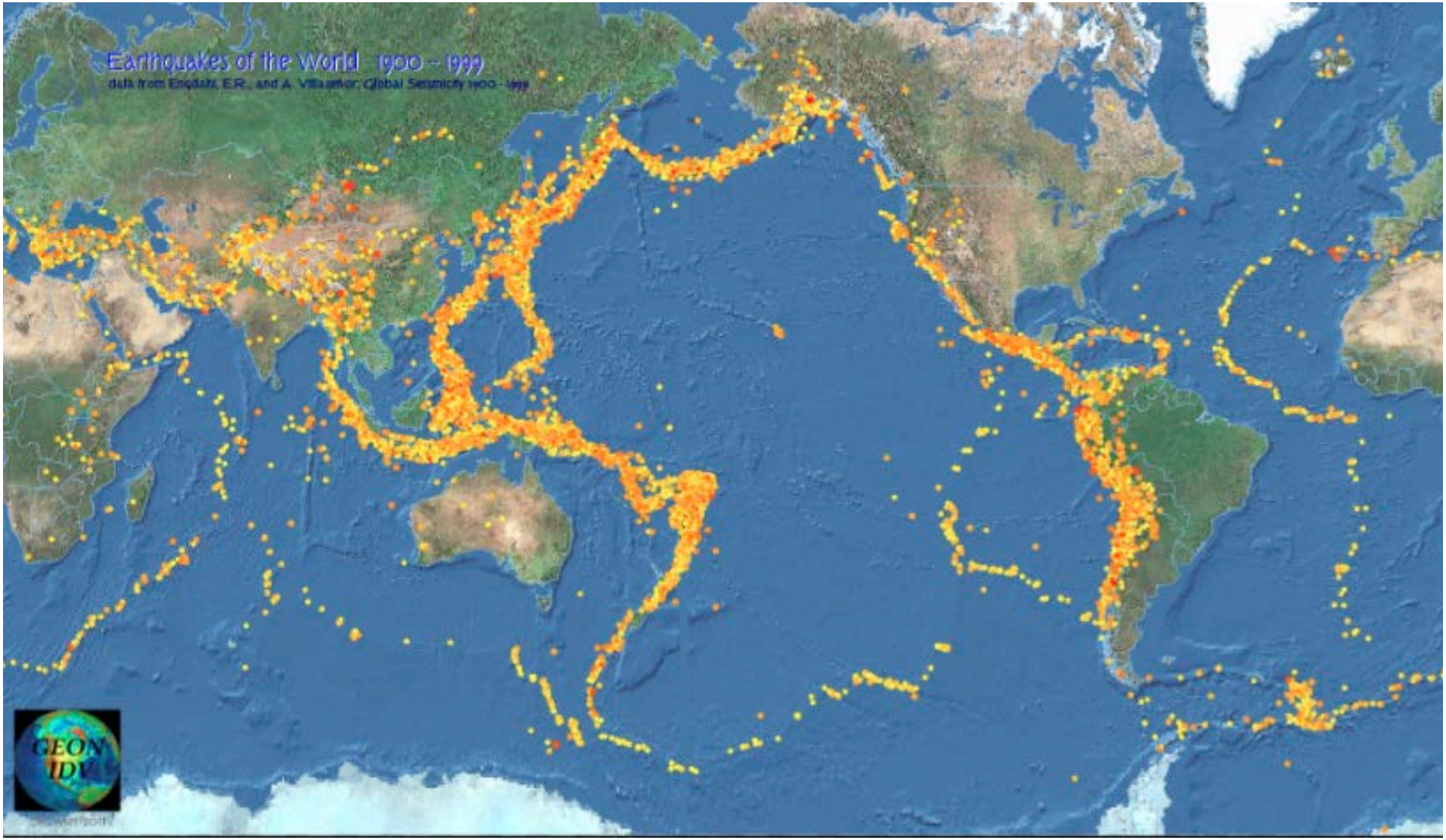


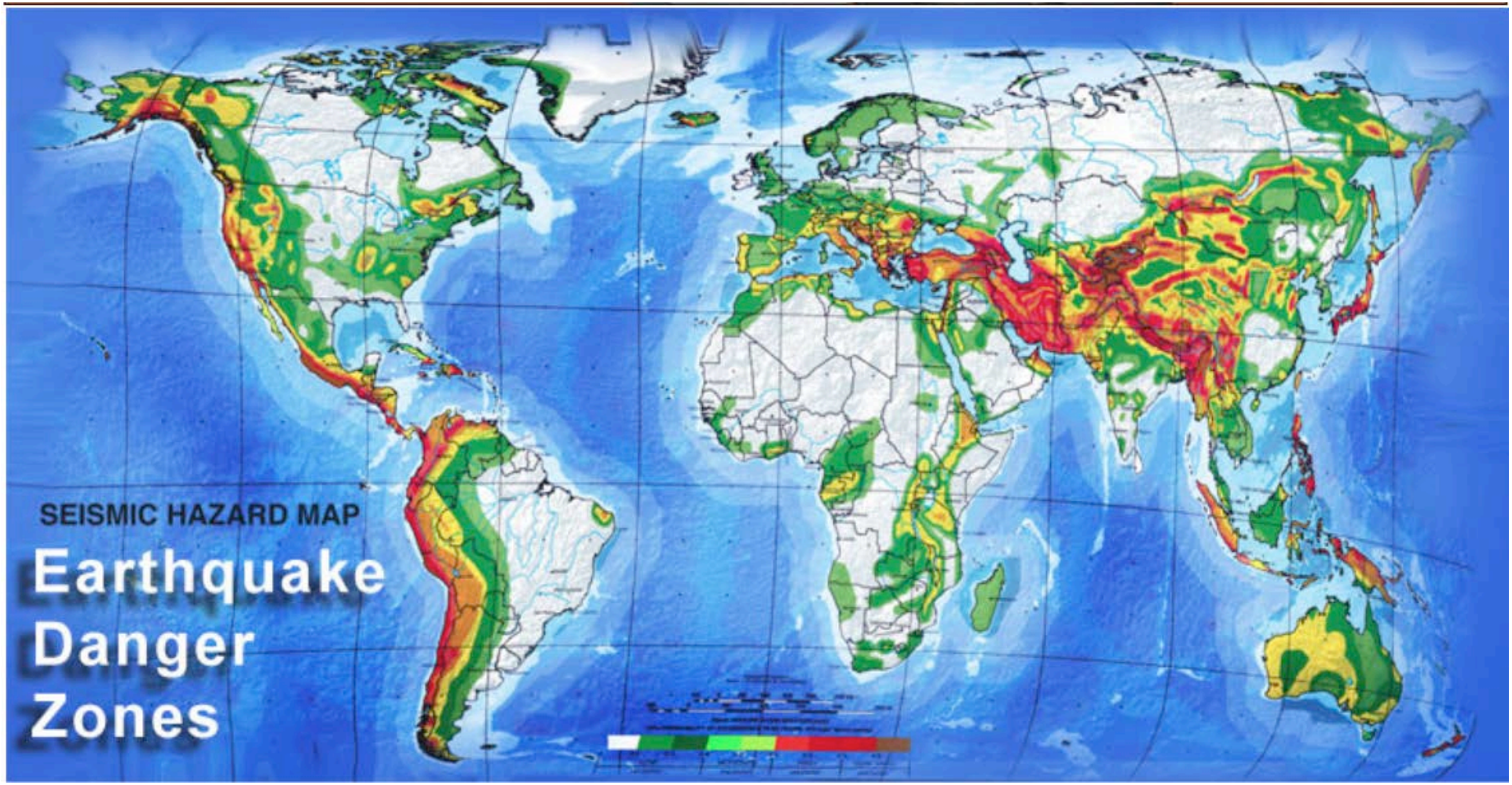
Source: Vancouver, City on the Edge



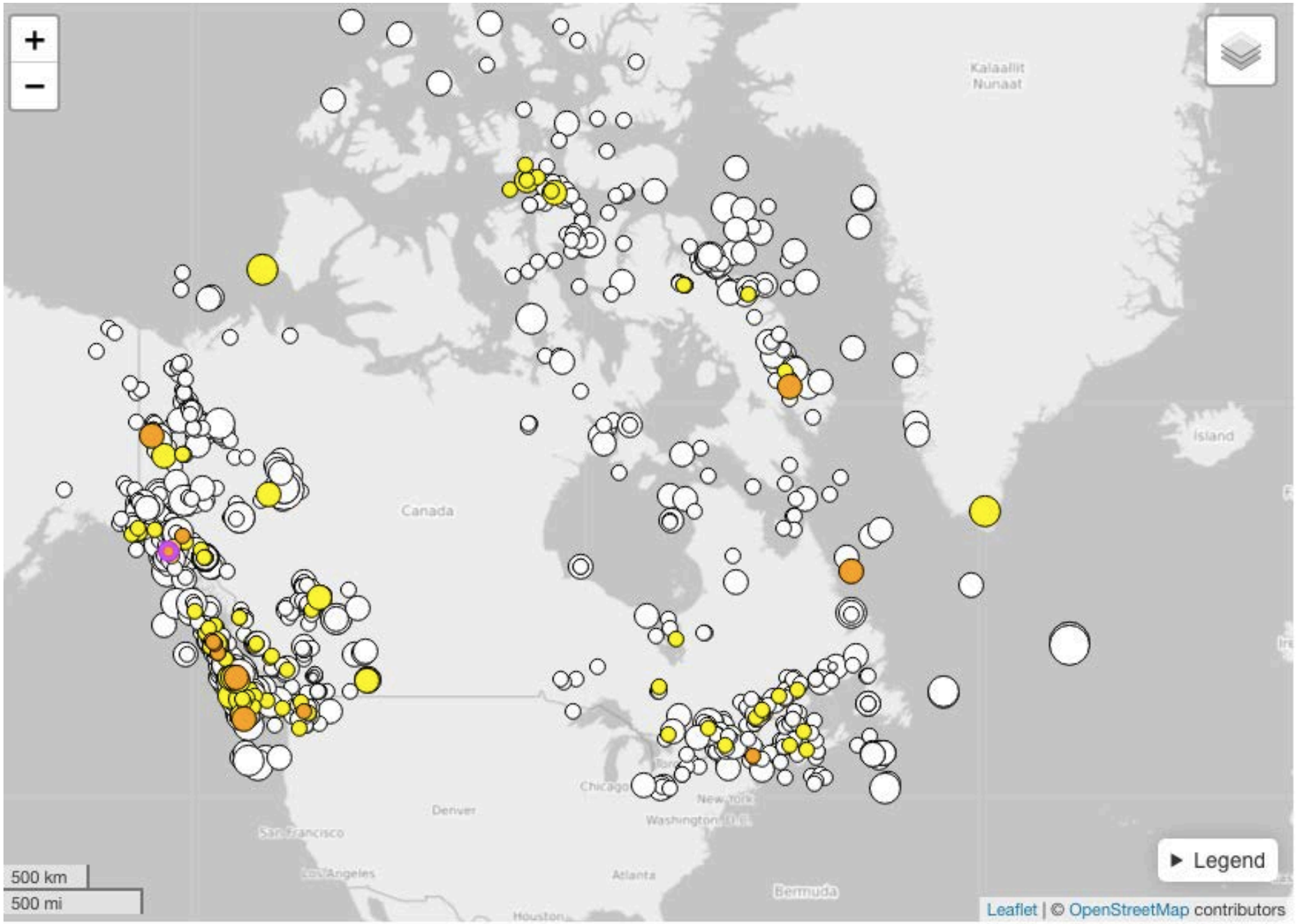
Summary

https://earthquakescanada.nrcan.gc.ca/recent/maps-cartes/index-1y-en.php


Earthquakes of the World 1900 - 1999
data from Engdahl, E.R., and A. Villaseñor, Global Seismicity 1900 - 1999
GEON IDV


SEISMIC HAZARD MAP
Earthquake
Danger
Zones


Some earthquakes are so tiny we can't feel them,
others are deadly and destructive.
More than a million small earthquakes are
recorded around the world every year.
Italy, April 2009
www.foxnews.com



Summary

https://earthquakescanada.nrcan.gc.ca/recent/maps-cartes/index-1y-en.php

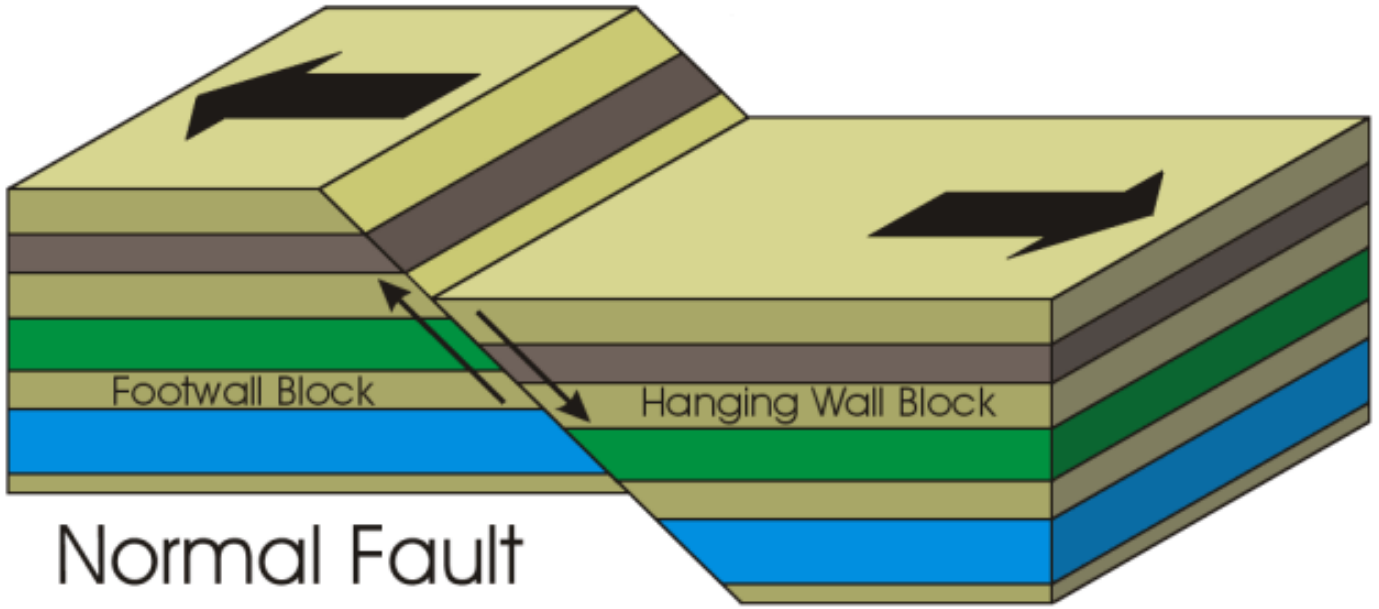
It not my fault! Not all earth movements are the same.

- A **FAULT** is a crack in the earth's surface where movement has occurred – they can be a few metres to hundreds of kilometres long.

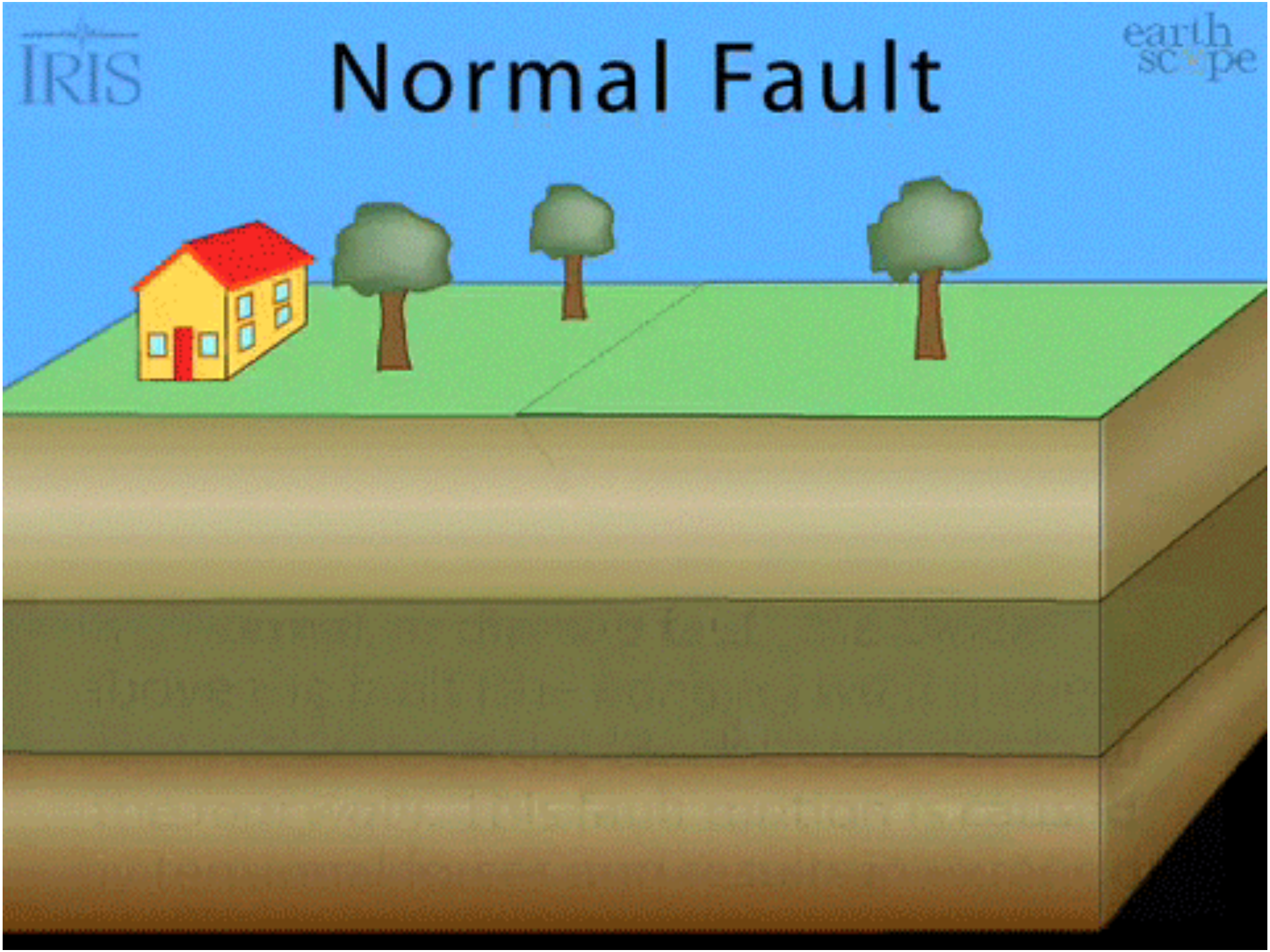
- Some faults are very active and move frequently, others are quiet and have not moved in hundreds of years.

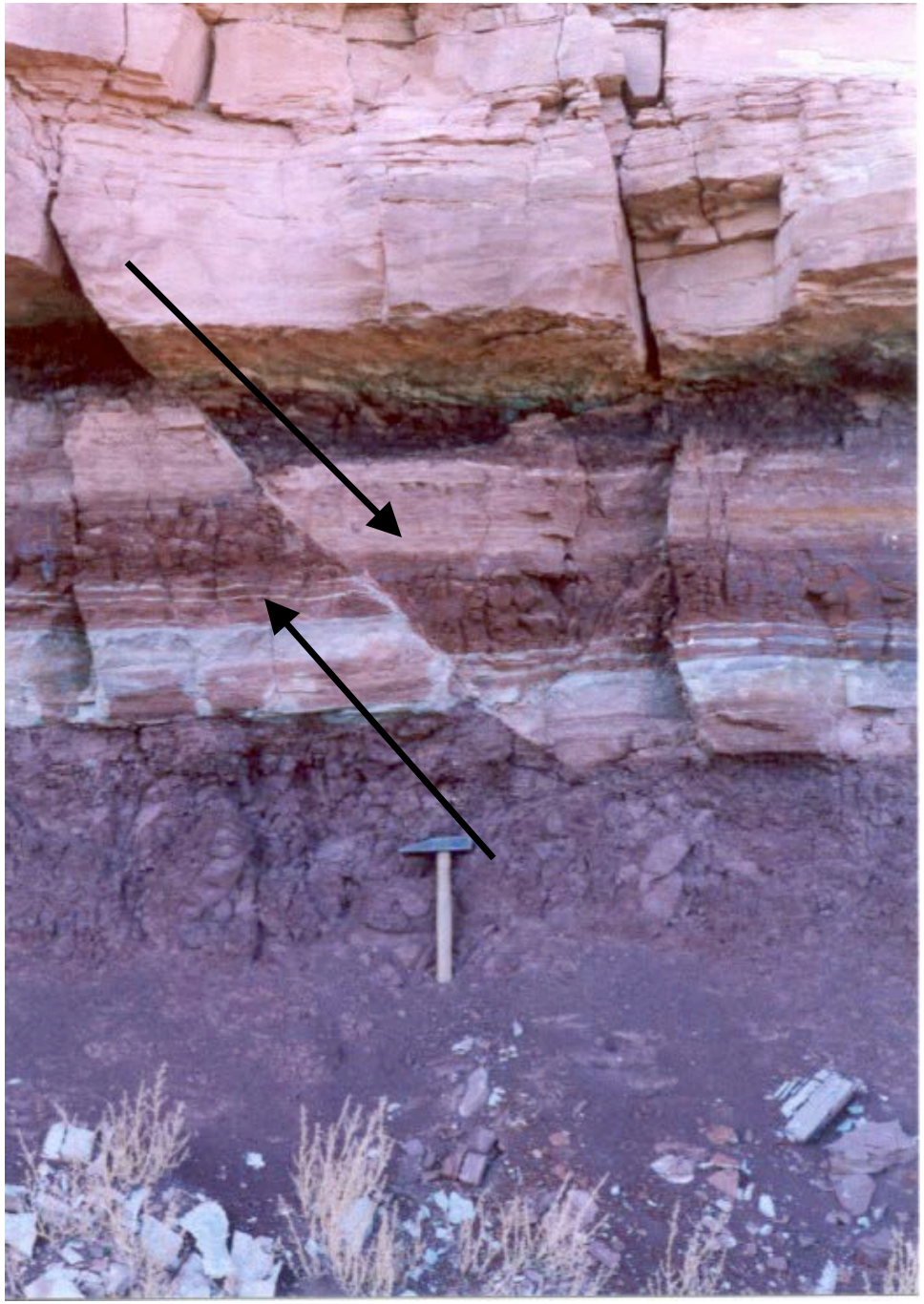
Normal Fault

- When rock is stretched apart or in tension, one side of the fault slips down relative to the other.



http://facweb.bhc.edu/academics/science/harwoodr/Geol101/study/Images/NormalFault.gif


IRIS
Normal Fault
earth scope



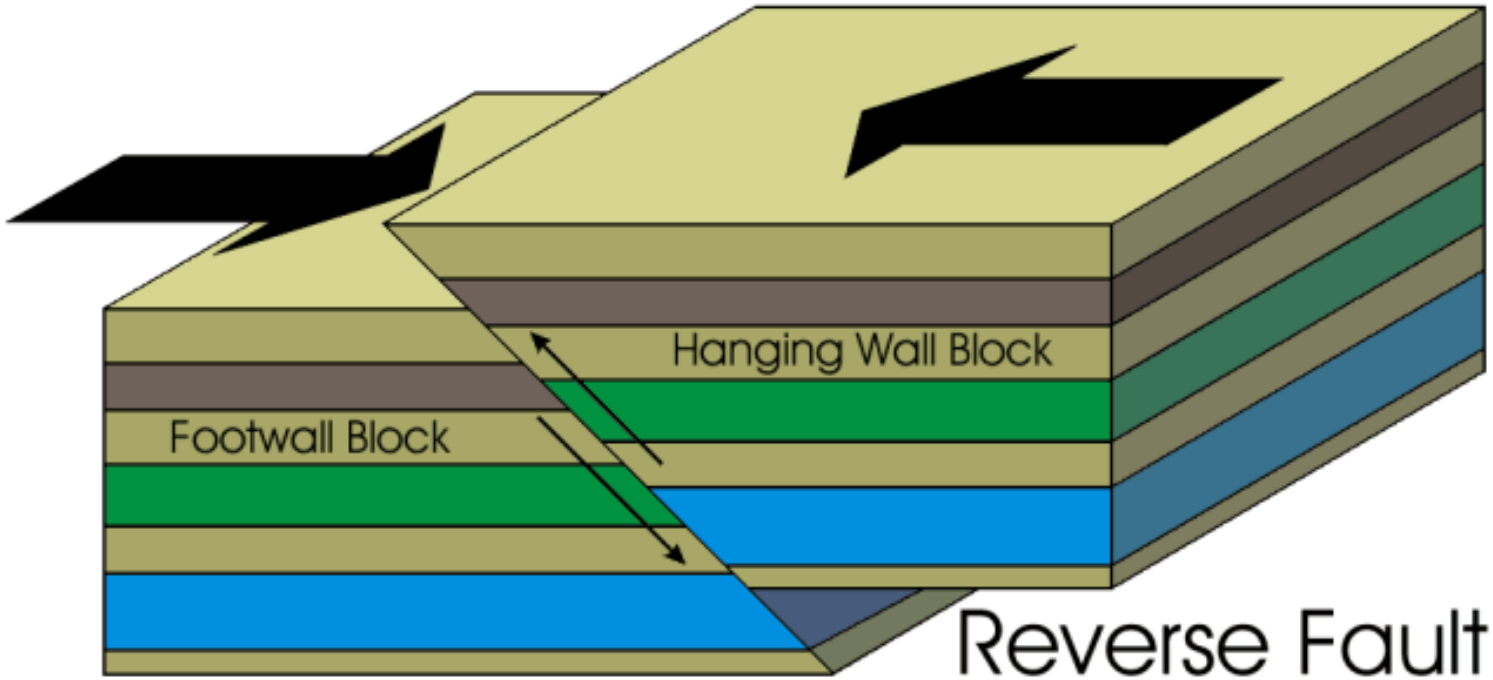
Normal Fault

Small normal fault with 10cm displacement. Utah, USA.

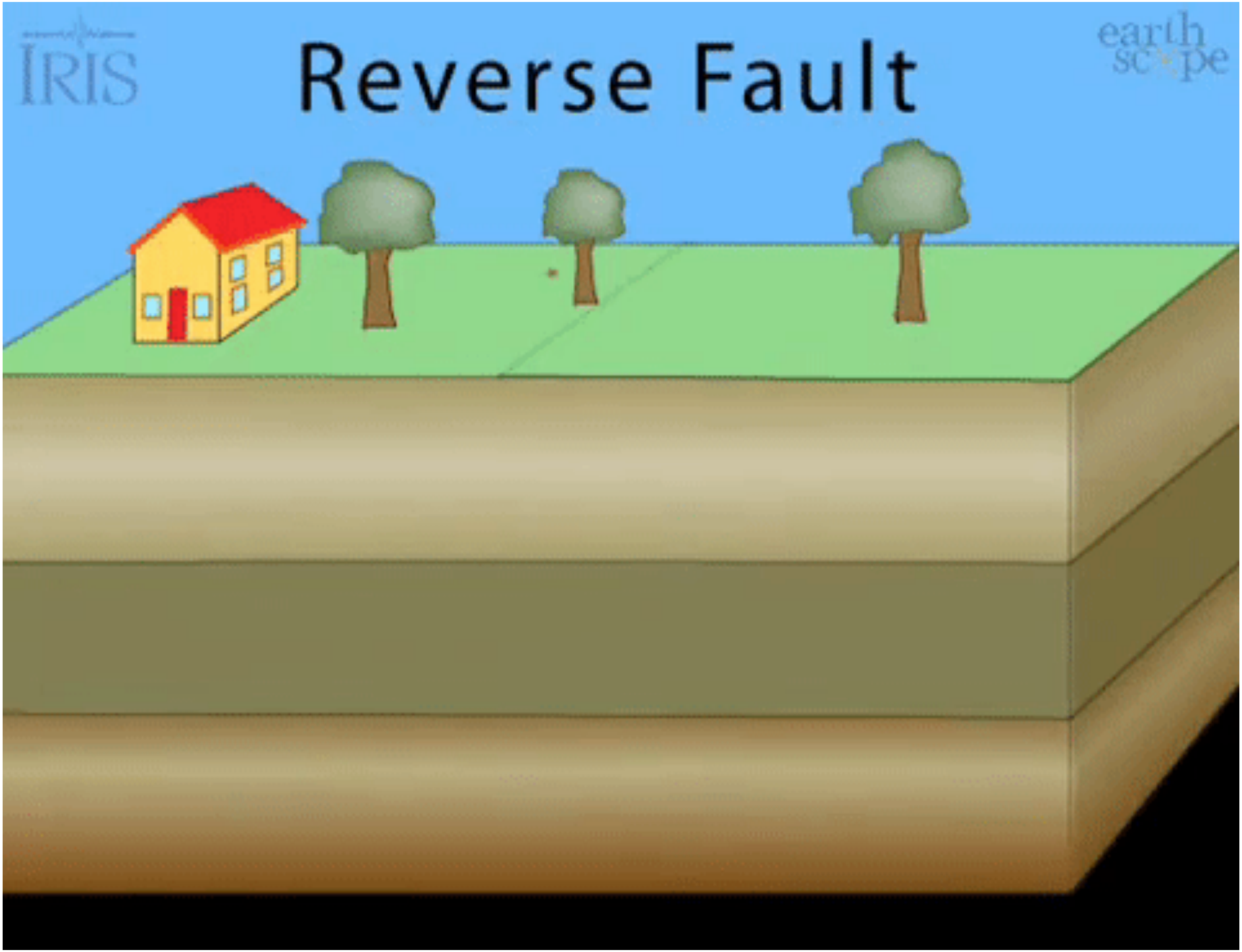
http://www.fault-analysis-group.ucd.ie/gallery/Normal_faults.htm

Reverse Fault

- When rock is compressed (pushed) together – one side rises up
- Caused tsunami in Indonesia, Dec. 2004



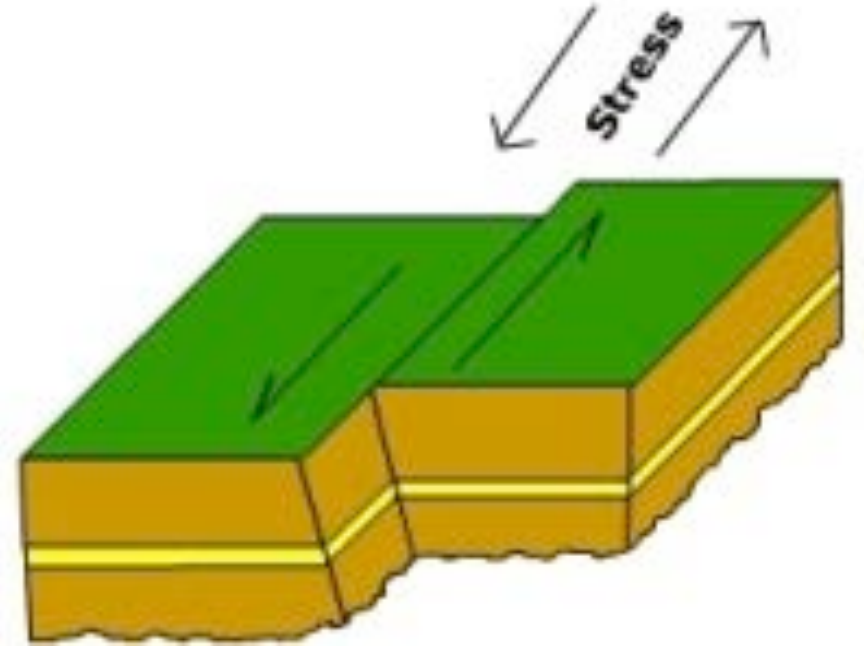
http://facweb.bhc.edu/academics/science/harwoodr/Geol101/study/Images/ReverseFault.gif


IRIS
Reverse Fault
earth scope

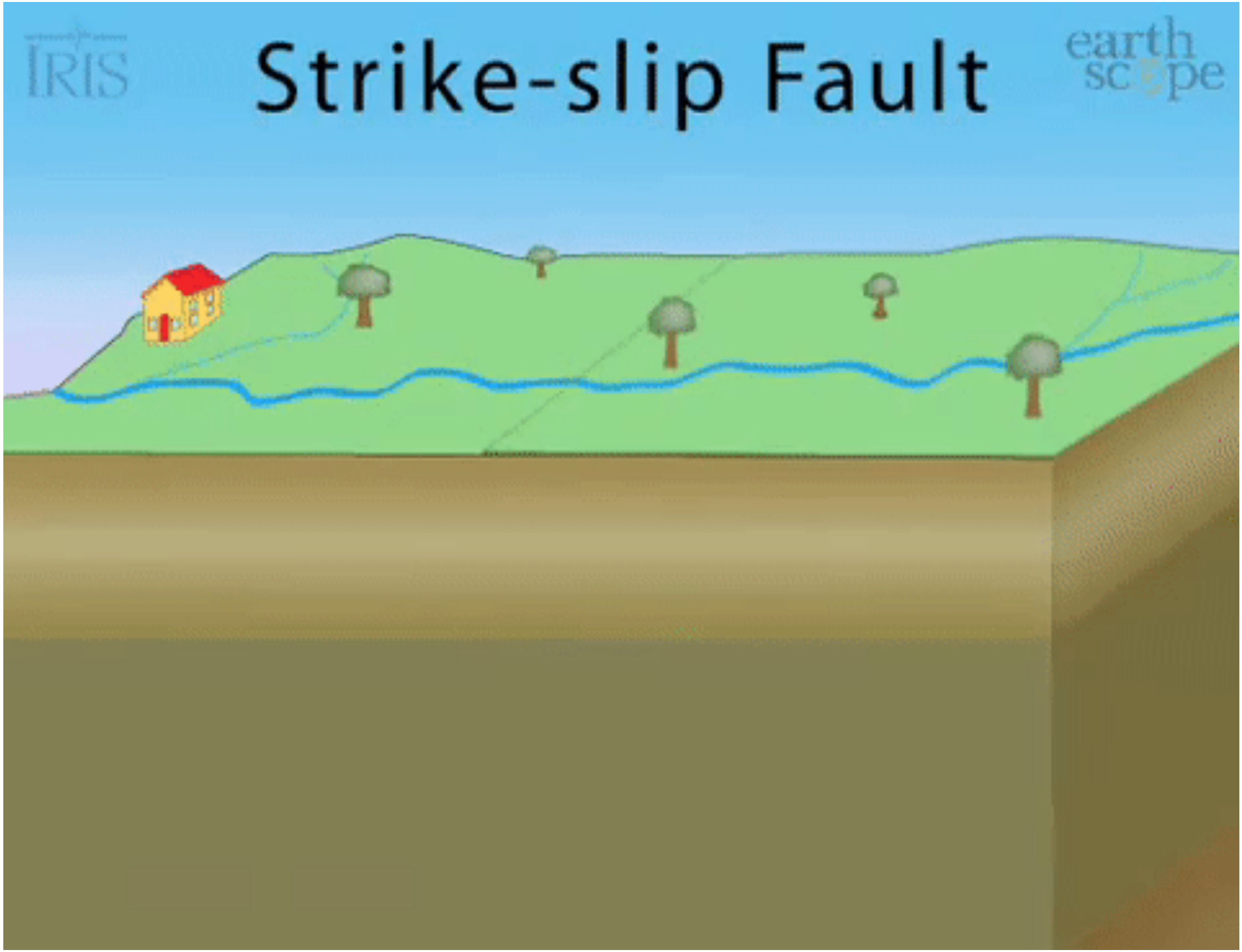

This side of the fault has moved up relative to the side on the left showing that it's a REVERSE fault.
www.pitt.edu/ – photo Norris Jones

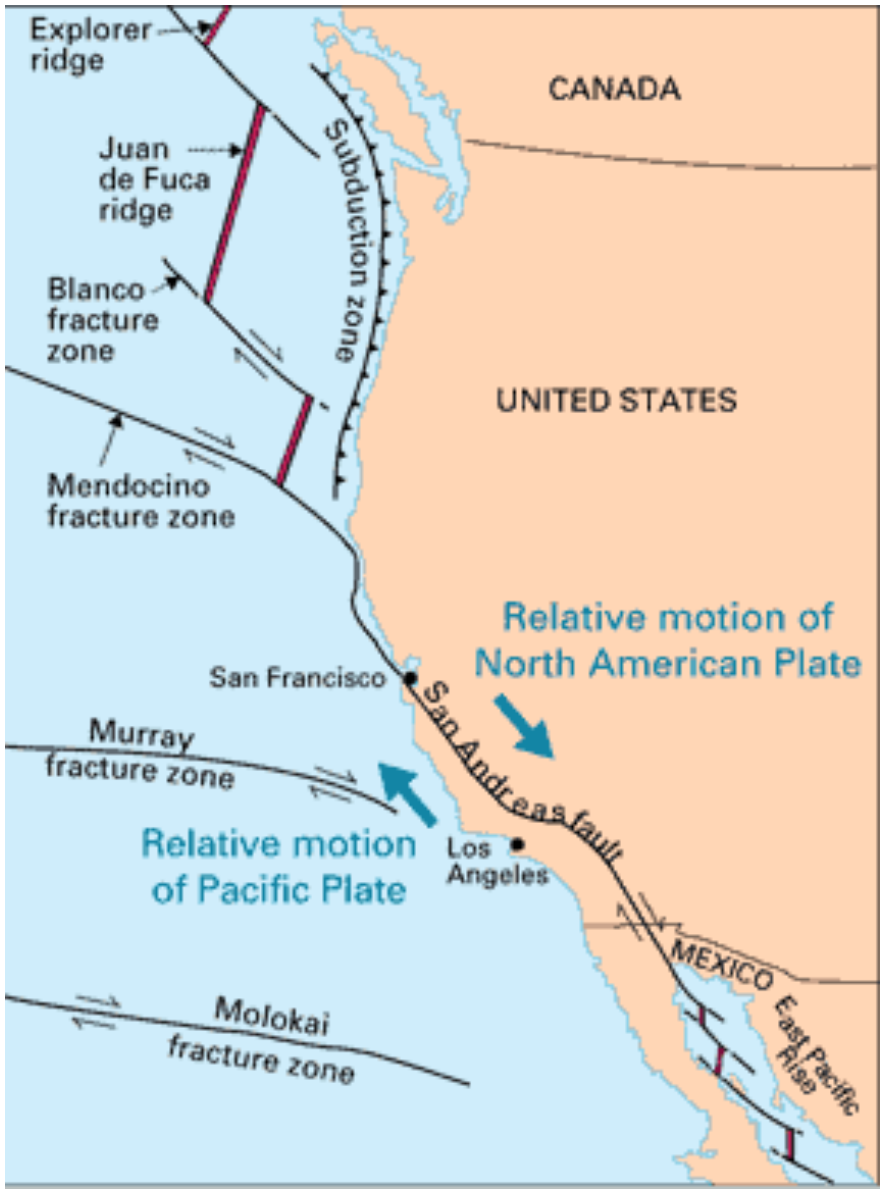
Transform (Strike-Slip) Fault

- Like a sliding plate boundary – two plates slide past each other – each one going in the opposite direction.
- Ex - San Andrea's Fault in California.
- Shallow earthquakes are often felt along these faults



www.uwsp.edu/geo/faculty/ritter/images/


IRIS
Strike-slip Fault
earthscope

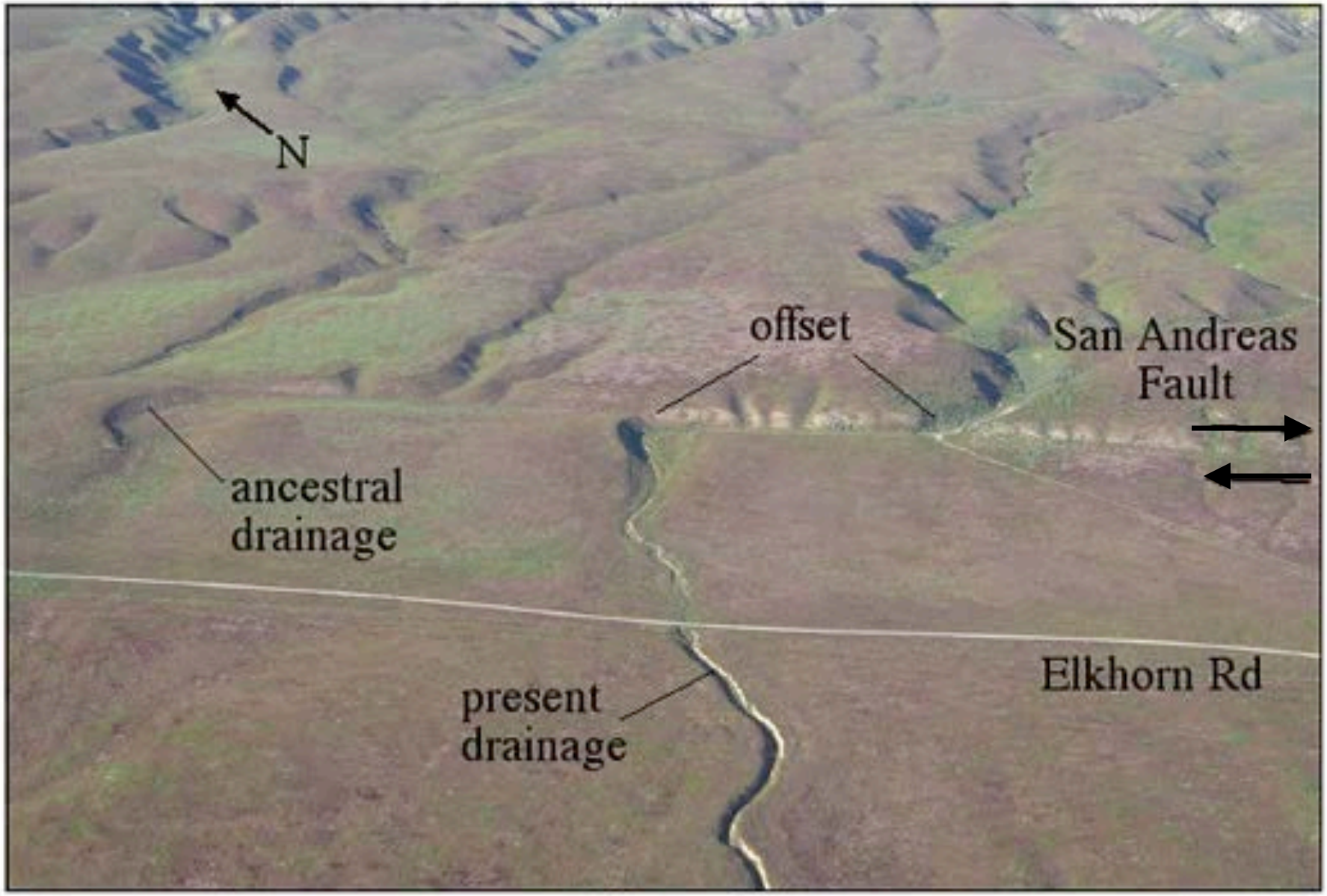


http://pubs.usgs.gov/gip/dynamic/graphics/Fig25.gif

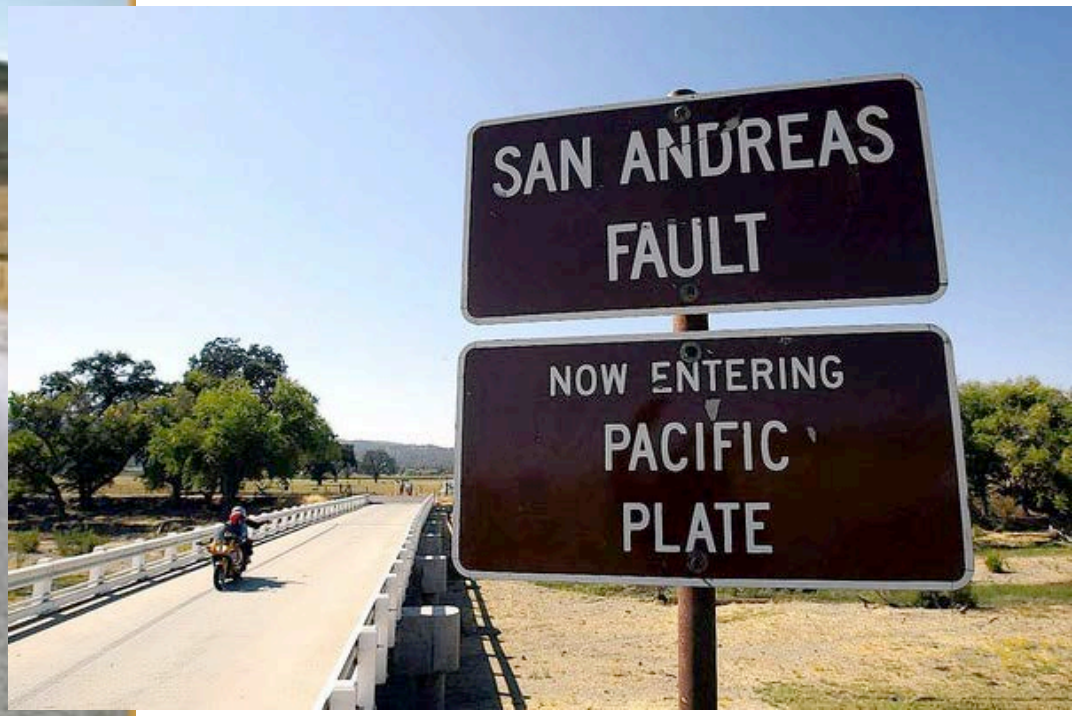
San Andreas Transform Fault

The San Andreas Fault is the sliding boundary between the Pacific Plate and the North American Plate. It slices California in two from Cape Mendocino to the Mexican border.

Wallace Creek



http://geology.com/articles/san-andreas-fault.shtml


SAN ANDREAS
FAULT
NOW ENTERING
PACIFIC
PLATE

Measuring Earthquakes

- **The Moment Magnitude Scale** (most still refer to Richter Scale) measures the **amount of energy released** in an earthquake.

- It's a logarithmic scale – one number higher on the scale is 30x more powerful. For example a **mag 6** is 30x more powerful than a **mag 5**

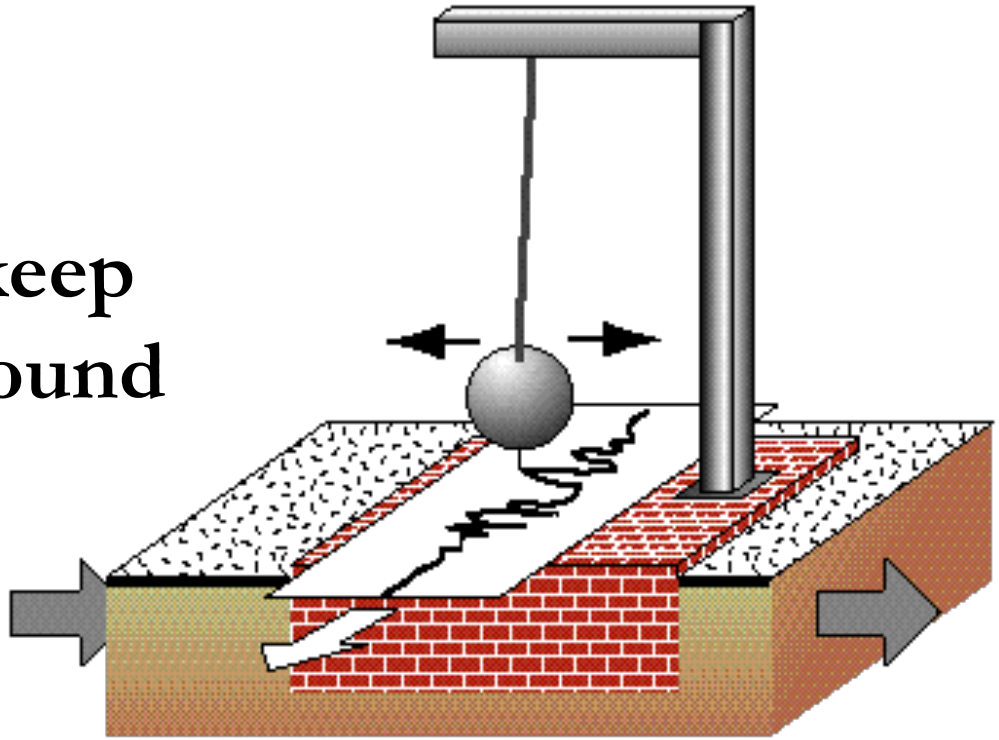
- Largest earthquake ever recorded was a 9.5 in Chile in 1960. Yikes!!


UNION

Measuring Earthquakes

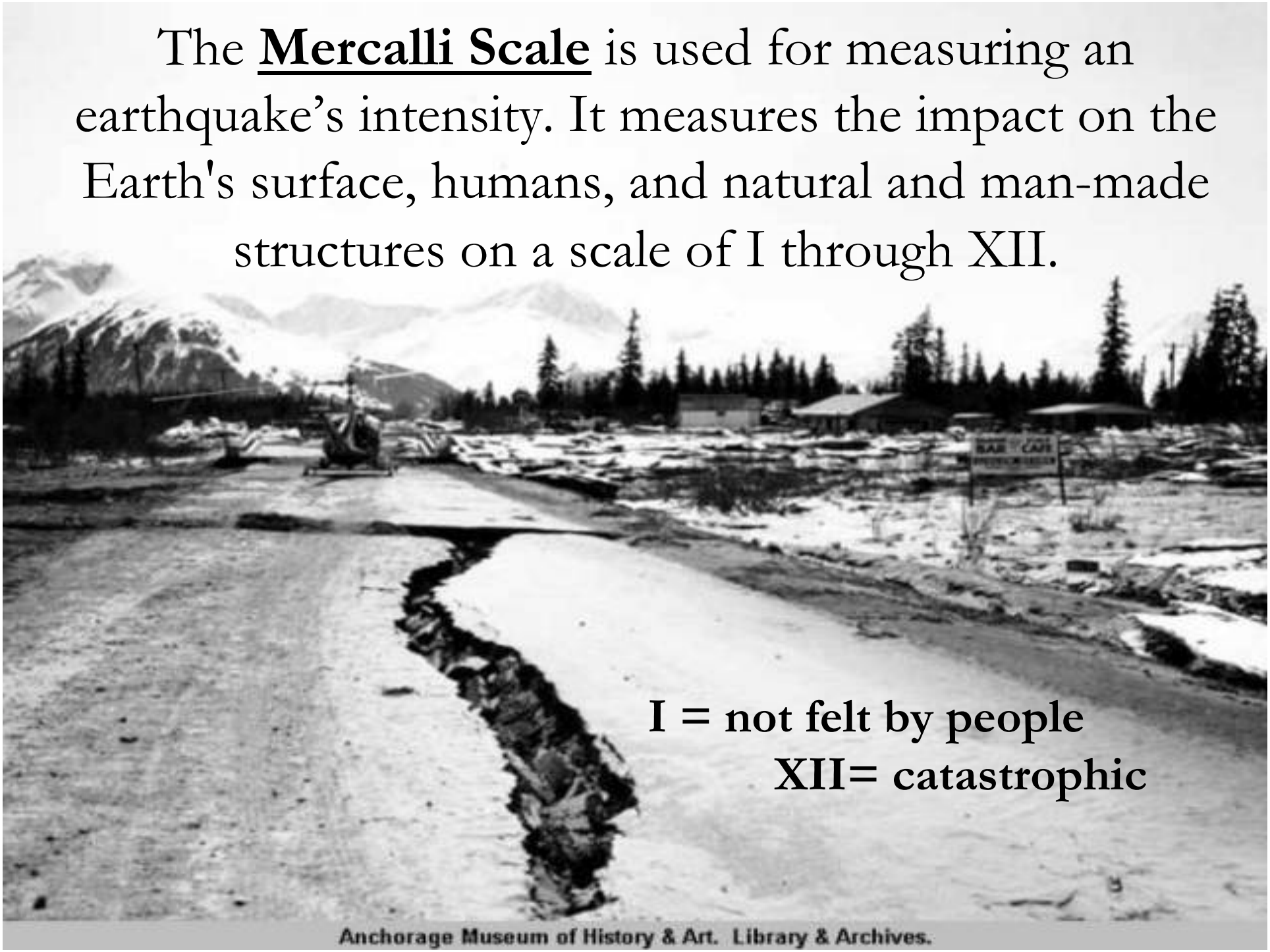
How do you think this seismograph works?

Why is it important to keep track of earthquakes around the world?



http://www.seismo.unr.edu/ftp/pub/louie/class/100/seismic-waves.html

The **Mercalli Scale** is used for measuring an earthquake's intensity. It measures the impact on the Earth's surface, humans, and natural and man-made structures on a scale of I through XII.



I = not felt by people

XII= catastrophic

Anchorage Museum of History & Art. Library & Archives.

Earthquake 1:

7.0 on the Richter Scale

X (10) on the Mercalli Scale

Earthquake 2:

7.0 on the Richter Scale

II (2) on the Mercalli Scale

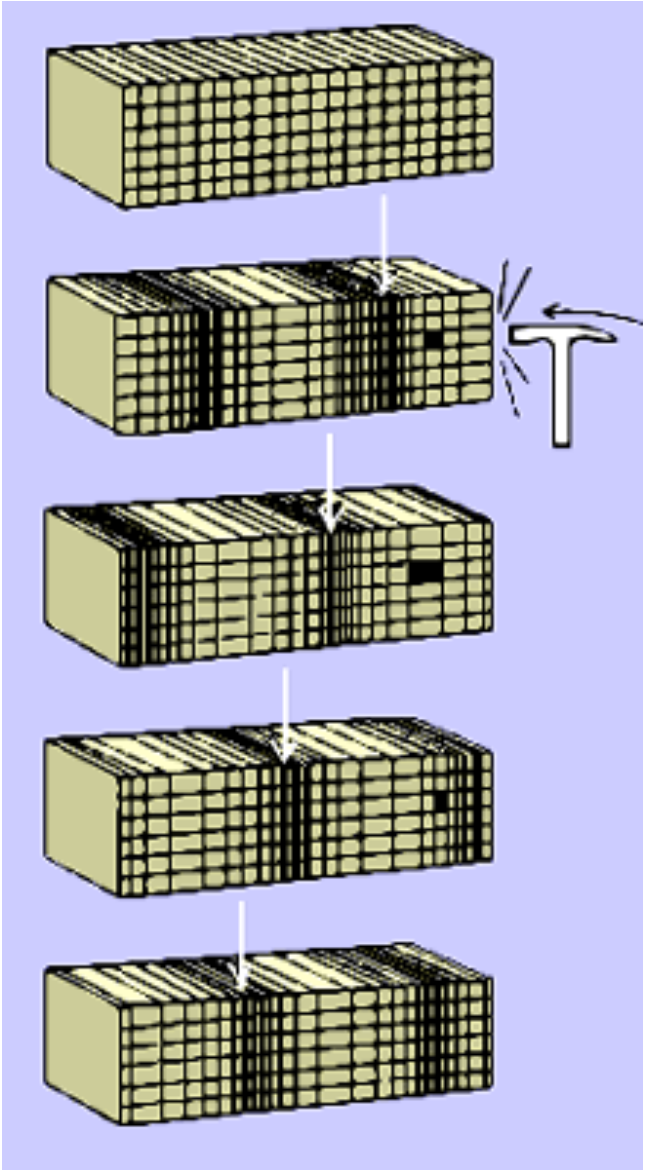
Is this possible? How?

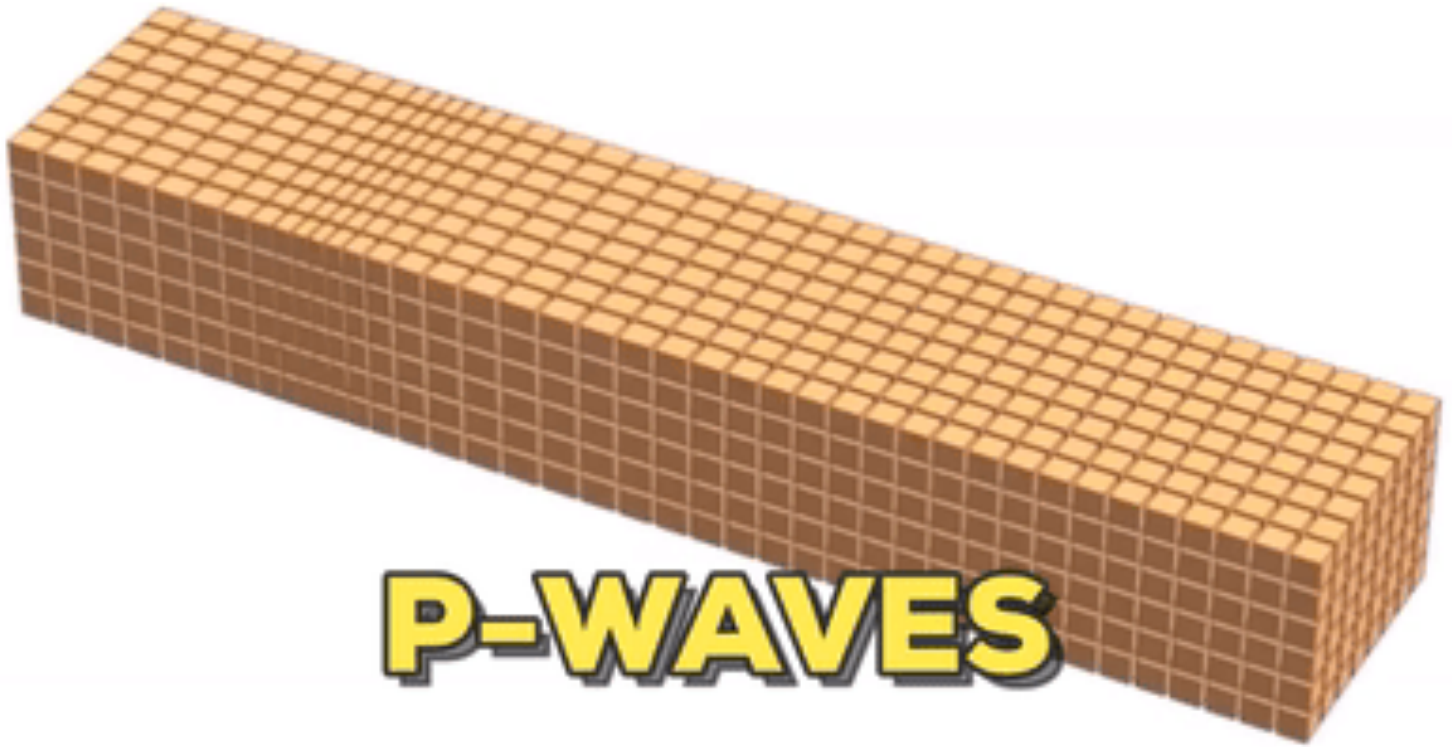
Earthquake Waves

Primary (P) Waves

- The first waves to be felt because they are the fastest
-
- Consist of contraction and expansion (pushing / pulling) which cause things to be jolted in a "back and forth" motion

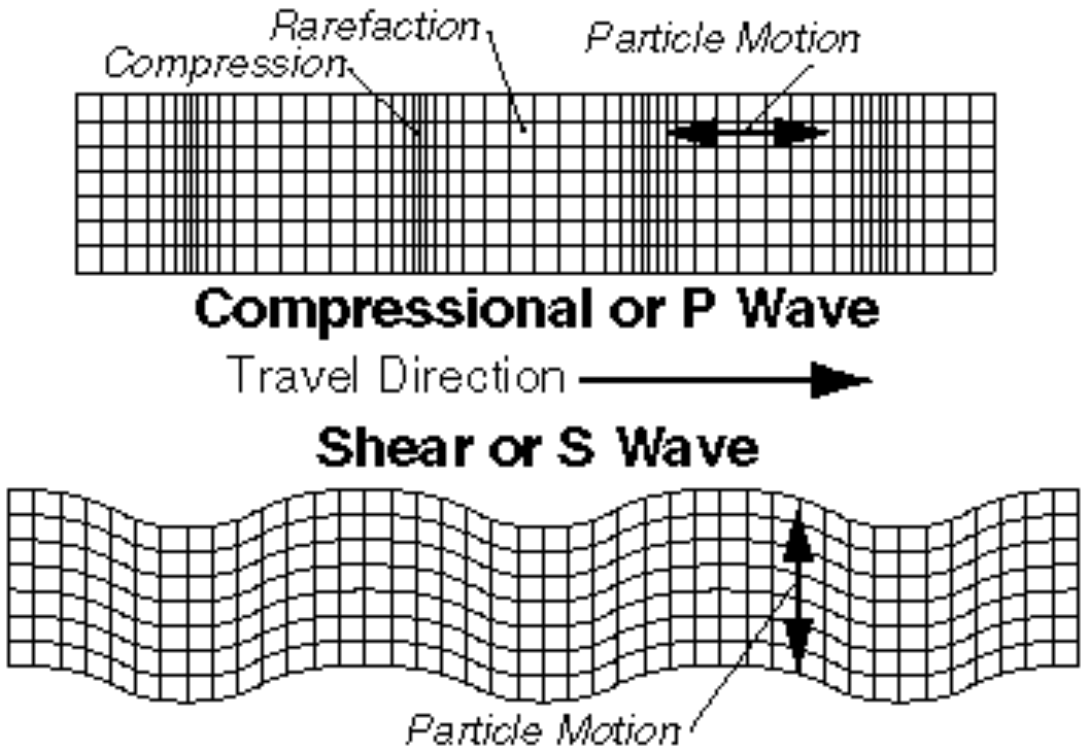
- Can travel through solids and liquids



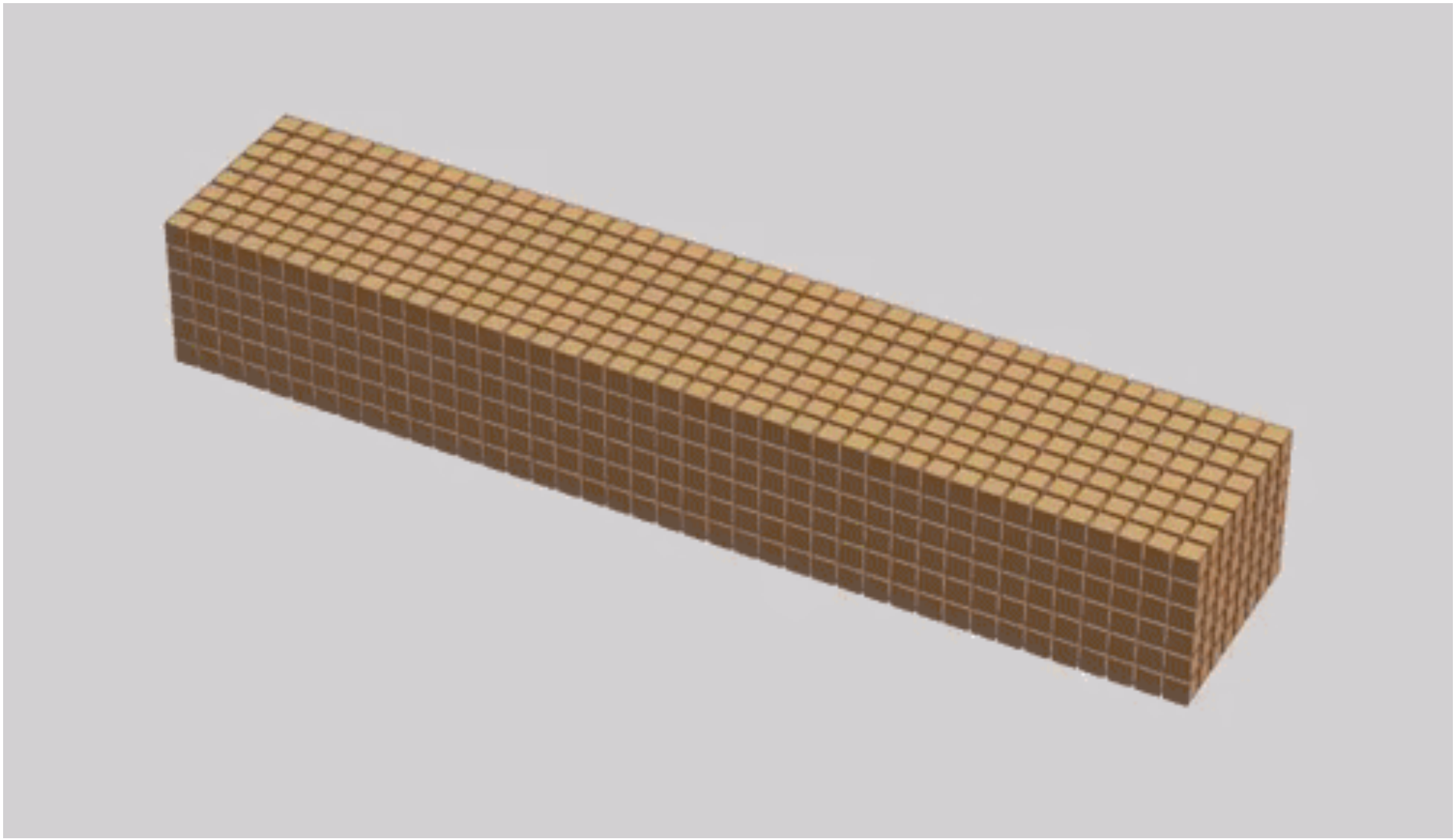

P-WAVES

Secondary (S) Waves

- move more slowly and are more destructive because they move rock particles up and down, or side-to-side--perpendicular to the direction that the wave is traveling
- Can only travel through **solids**



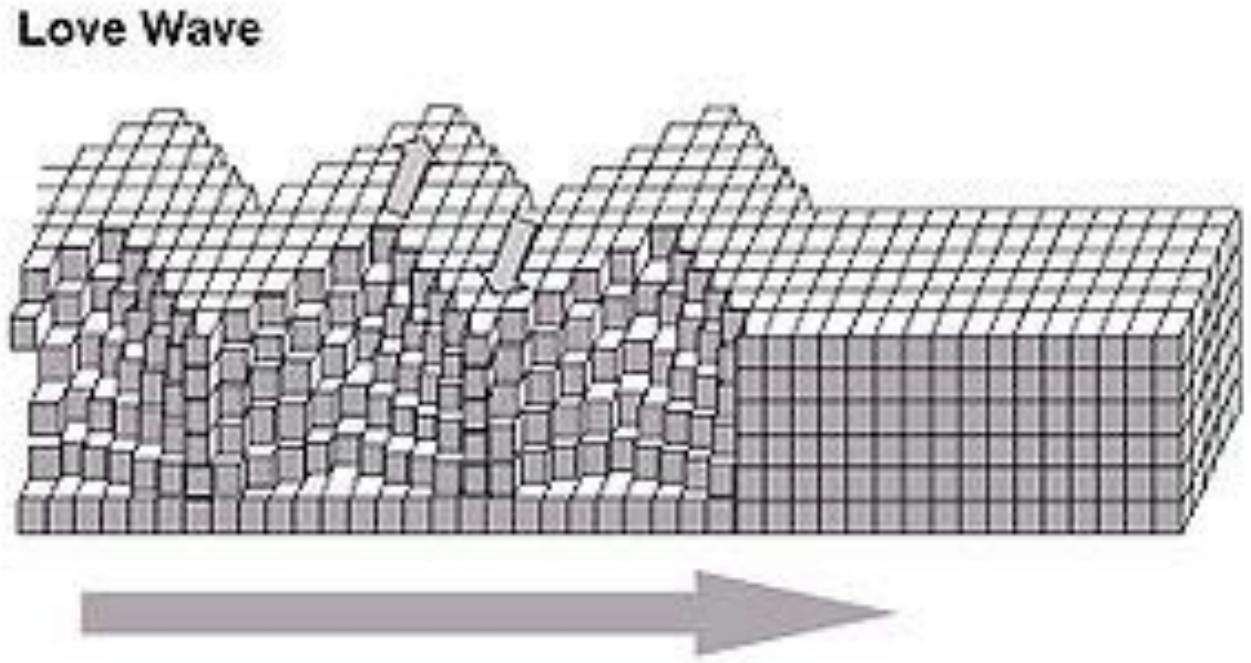
www.seismo.unr.edu

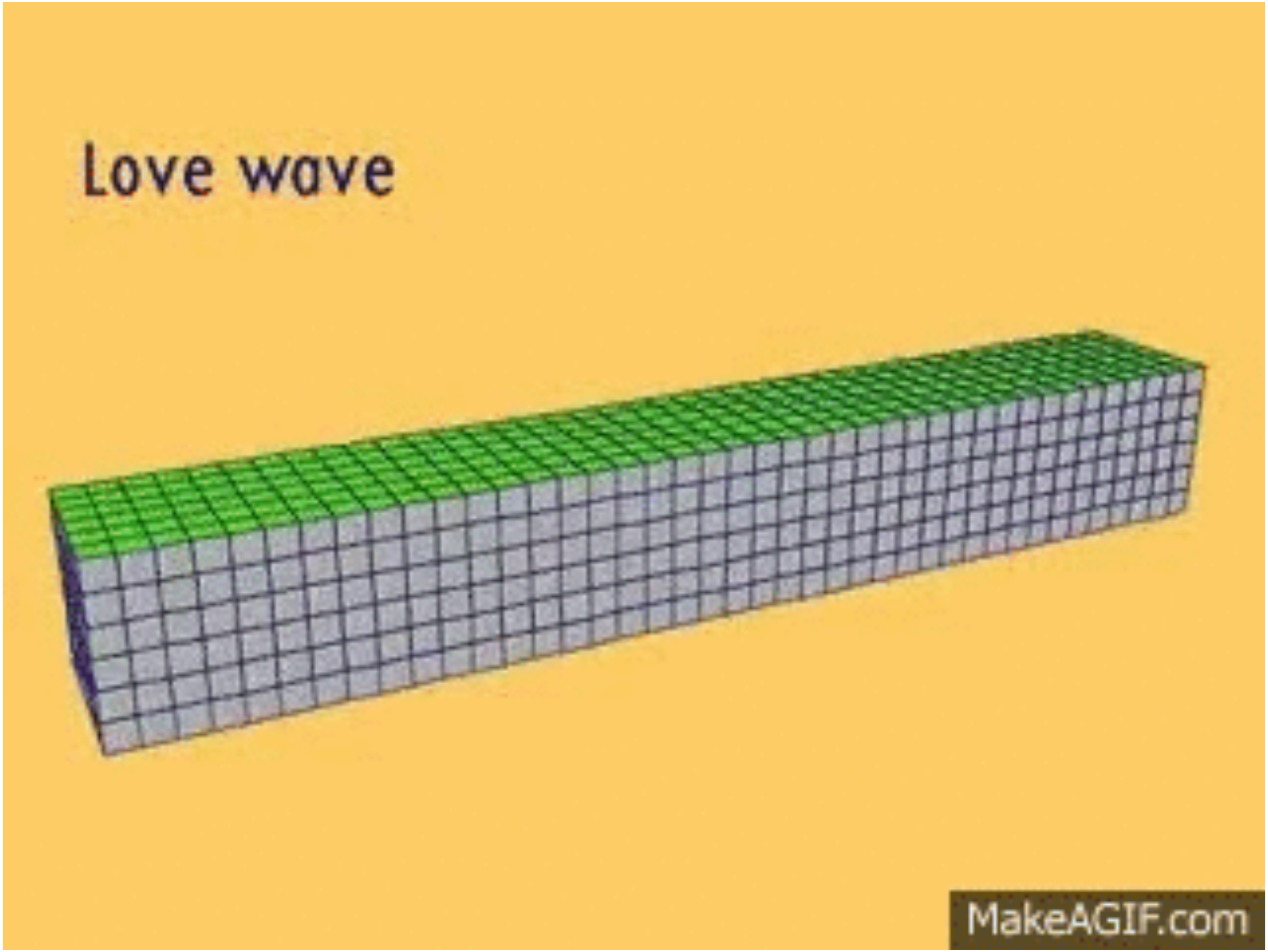


Surface (Love) Waves

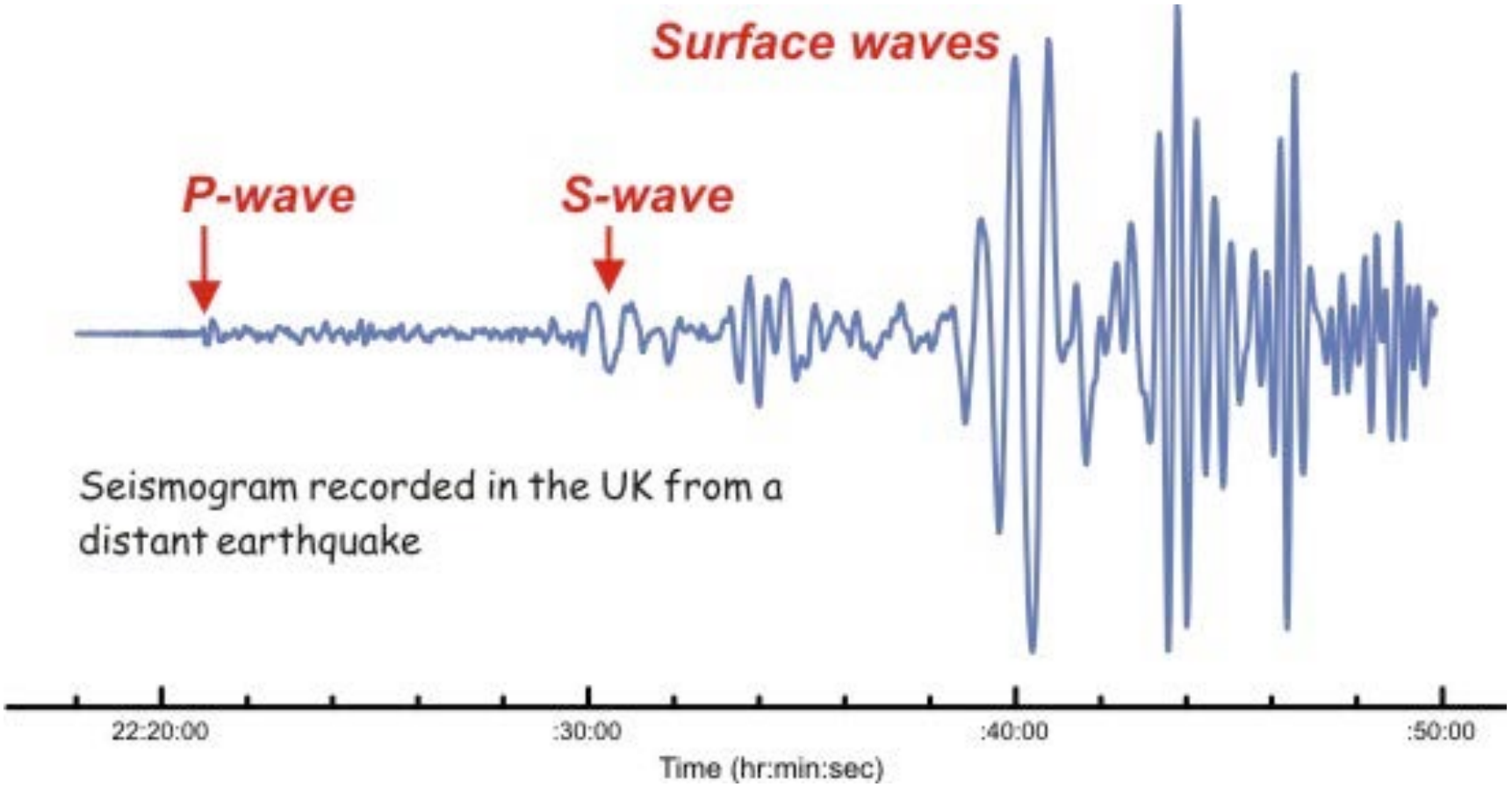
- most destructive because they are on the surface

- move like waves in water



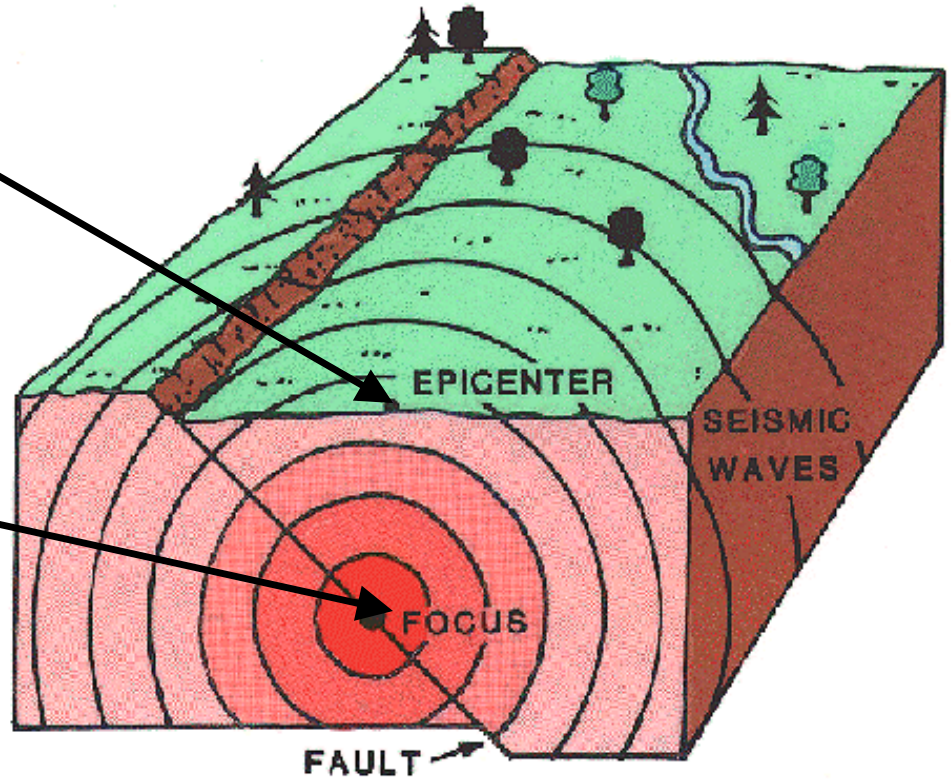

Love wave
MakeAGIF.com

Here's a look at how seismic waves arrive at an earthquake recording station.



Epicenter & Focus

- **EPICENTER**
  located at the surface directly above the focus
- **FOCUS**
  the place along the fault, and below the surface where the quake occurs



http://www.cyberphysics.pwp.blueyonder.co.uk/topics/earth/geophysics/Seismic%20Waves%20Reading.htm

Back to British Columbia

- Why is Vancouver at risk of "**The Big One**"?
- We are now long overdue for a major earthquake (over 9.0 on the MMS)
- Last 9.0 hit in 1700

Mainly cloudy
Details, C28

THE Province

60¢ Coin box: 75¢ Outside Lower Mainland: $1 minimum

Thursday, March 1, 2001 Vancouver, B.C www.theprovince.com

EIGHT-PAGE SPECIAL REPORT STARTS ON A2

QUAKE!

Powerful earthquake causes billions of dollars in damage to Seattle, and scares southern B.C.

Kristi Heim reacts to a crushed car and a collapsed wall at the Starbucks corporate headquarters building in Seattle yesterday.

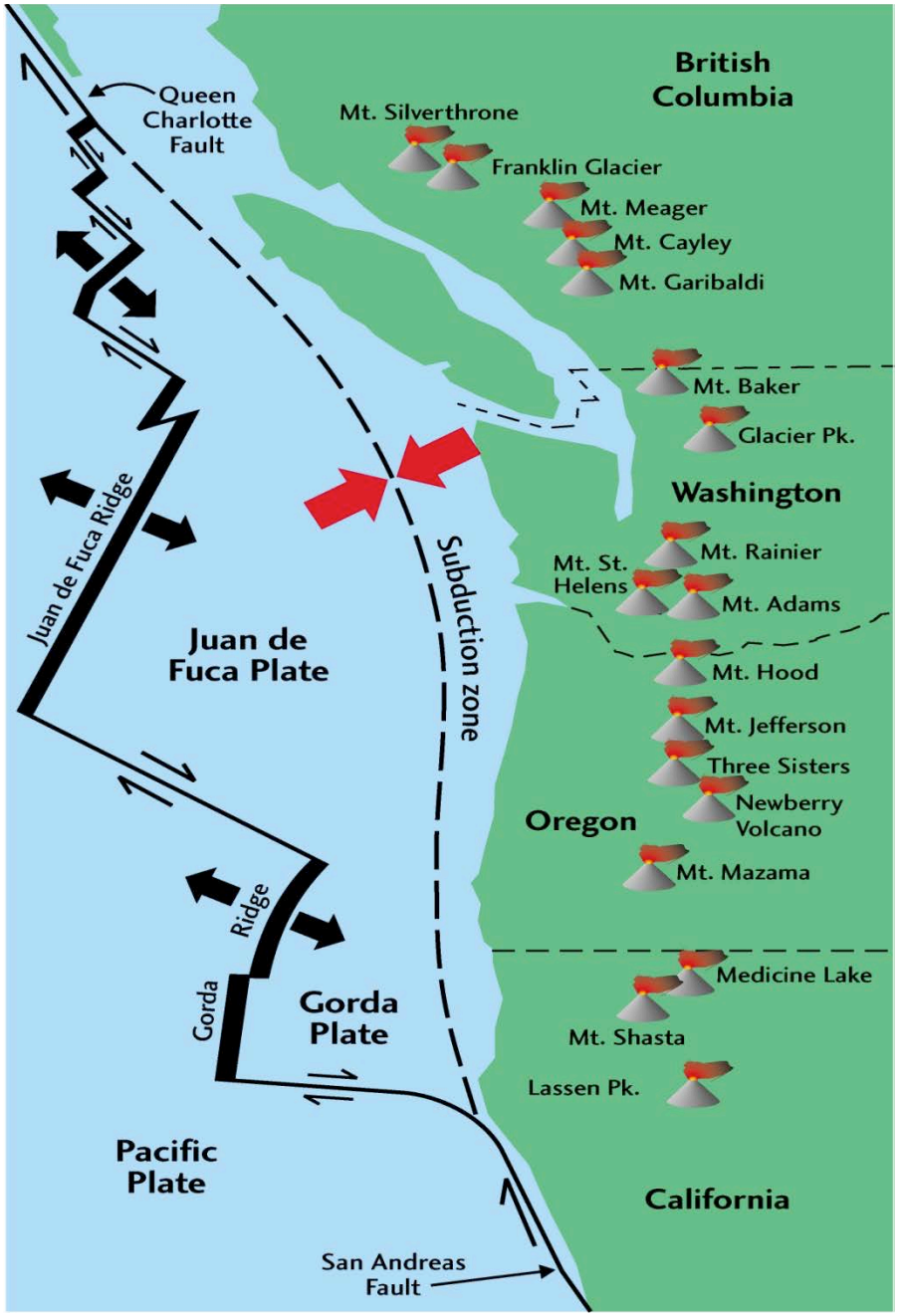
—Reuters

Source: Vancouver, City on the Edge

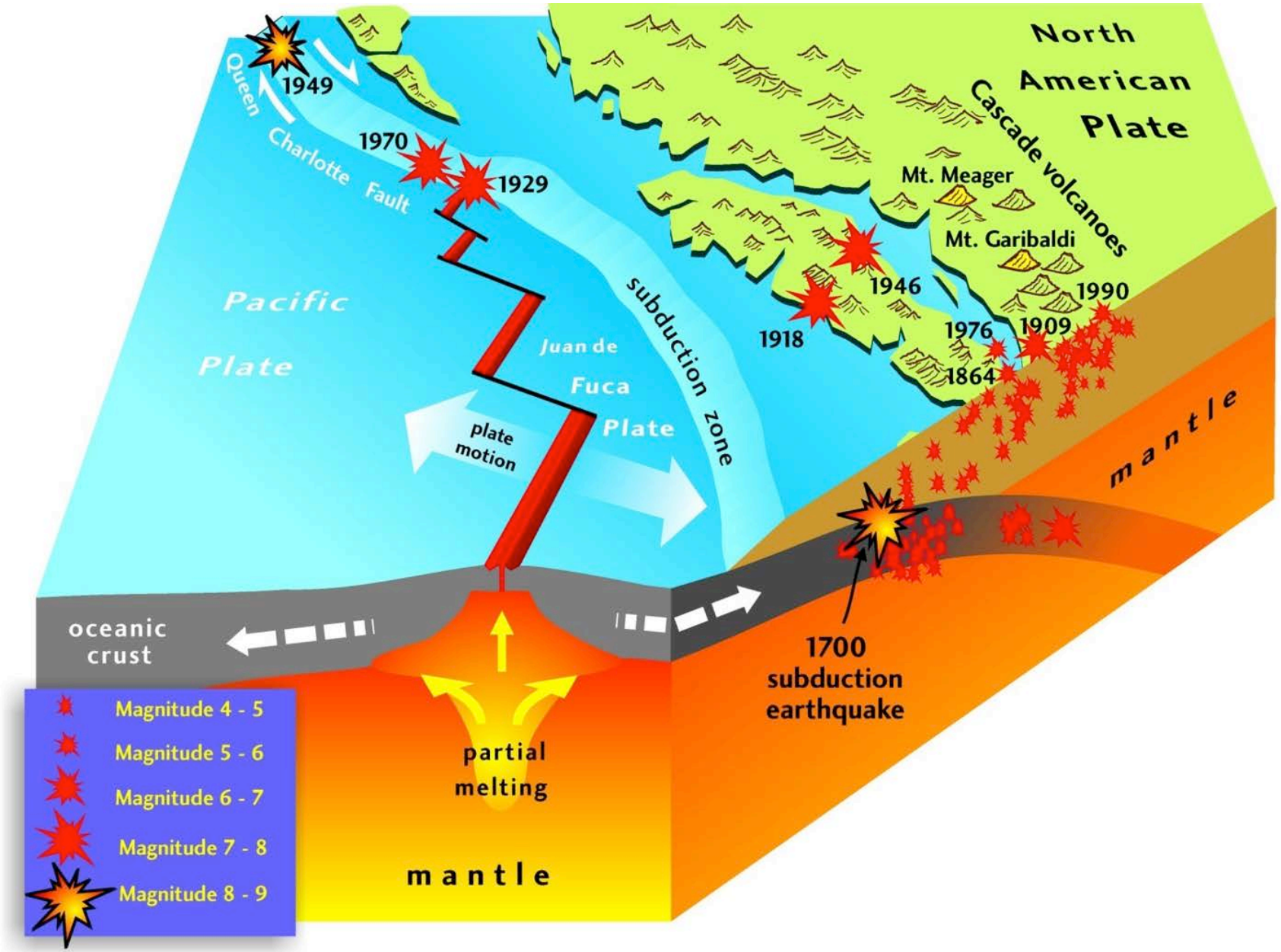
The biggest quake ever *recorded* on land in Canada was a 7.3, which struck in 1946 near Campbell River, BC.

The last, really big earthquake was an estimated magnitude 9 in 1700. A large tsunami occurred in Japan as a result.

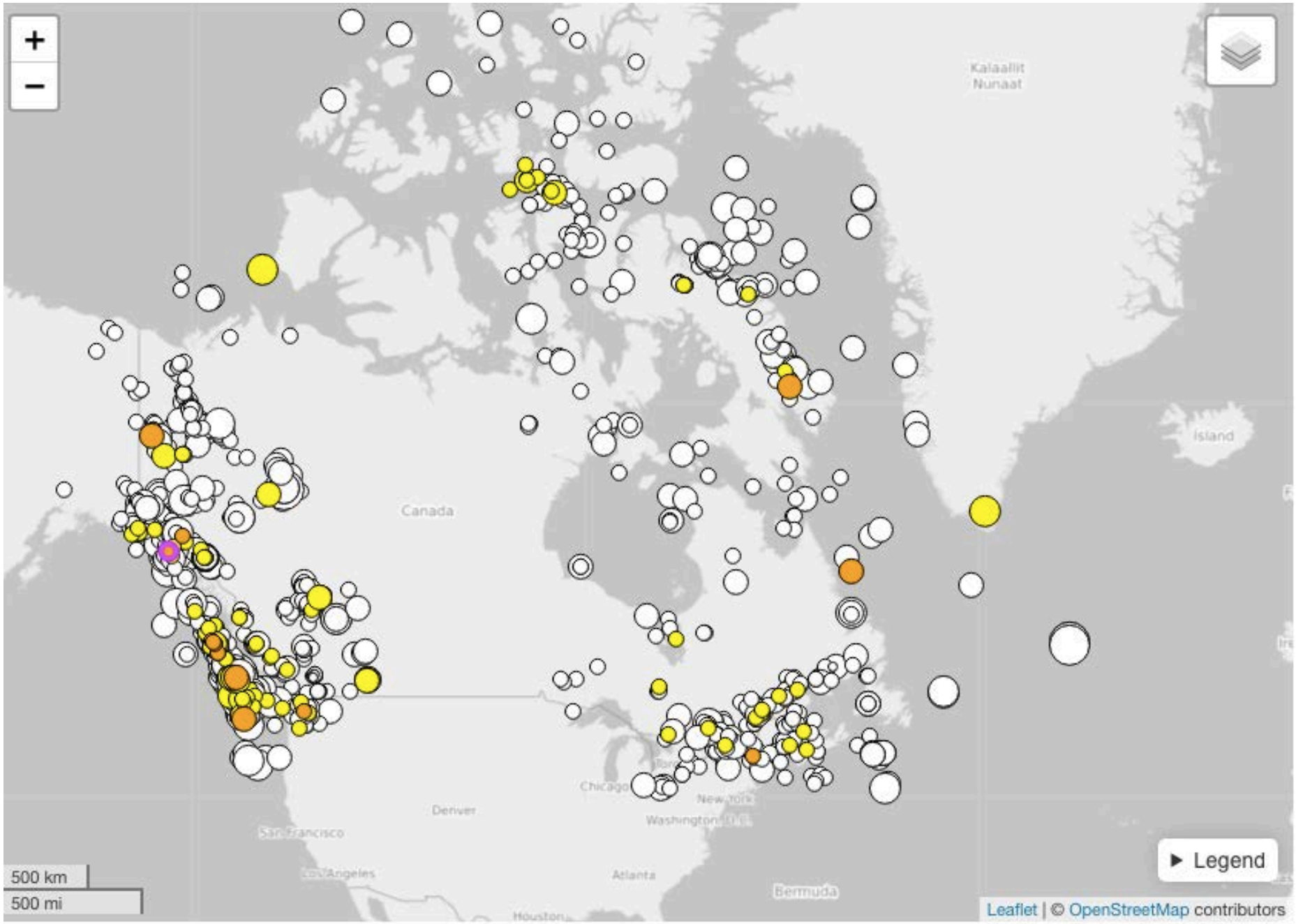
When will the next one happen??



Source: Vancouver, City on the Edge



Source: Vancouver, City on the Edge



Summary

https://earthquakescanada.nrcan.gc.ca/recent/maps-cartes/index-1y-en.php

Focus on Liquefaction

- Is is possible to build a structure with dry sand only?

- No – Why? The material is <u>unconsolidated</u> - refers to loose material like beach sand. The particles of an unconsolidated material can separate

- What are some different ways to make the sand stick together?

- Add Water – material becomes "consolidated" or compacted

Liquefaction continued

- Loose, unconsolidated material have spaces called “pores”
- If water fills this space the soil becomes saturated
- The water pushes the particles apart – this creates “pore pressure”

https://www.britannica.com/video/185615/liquefaction-event-soil-particles-earthquake-combination-water

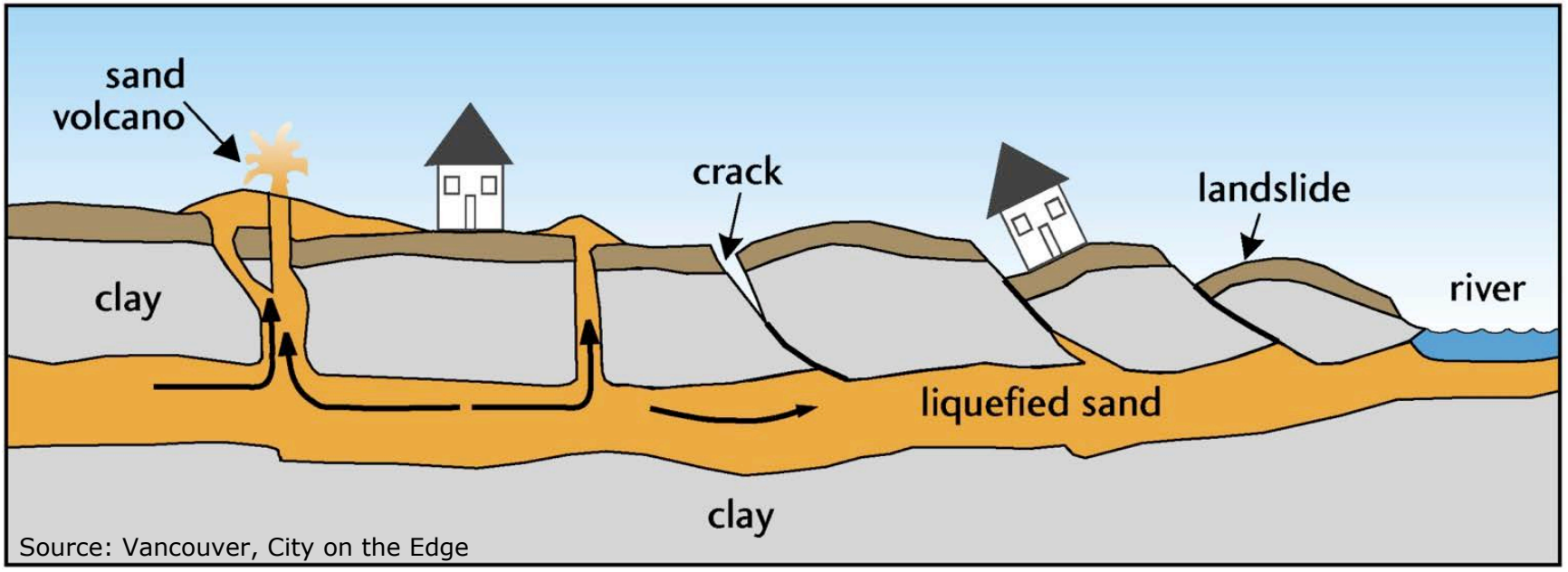
Demonstration– simulating liquefaction

- Predication - what happen is if I tap on the box with dry soils?

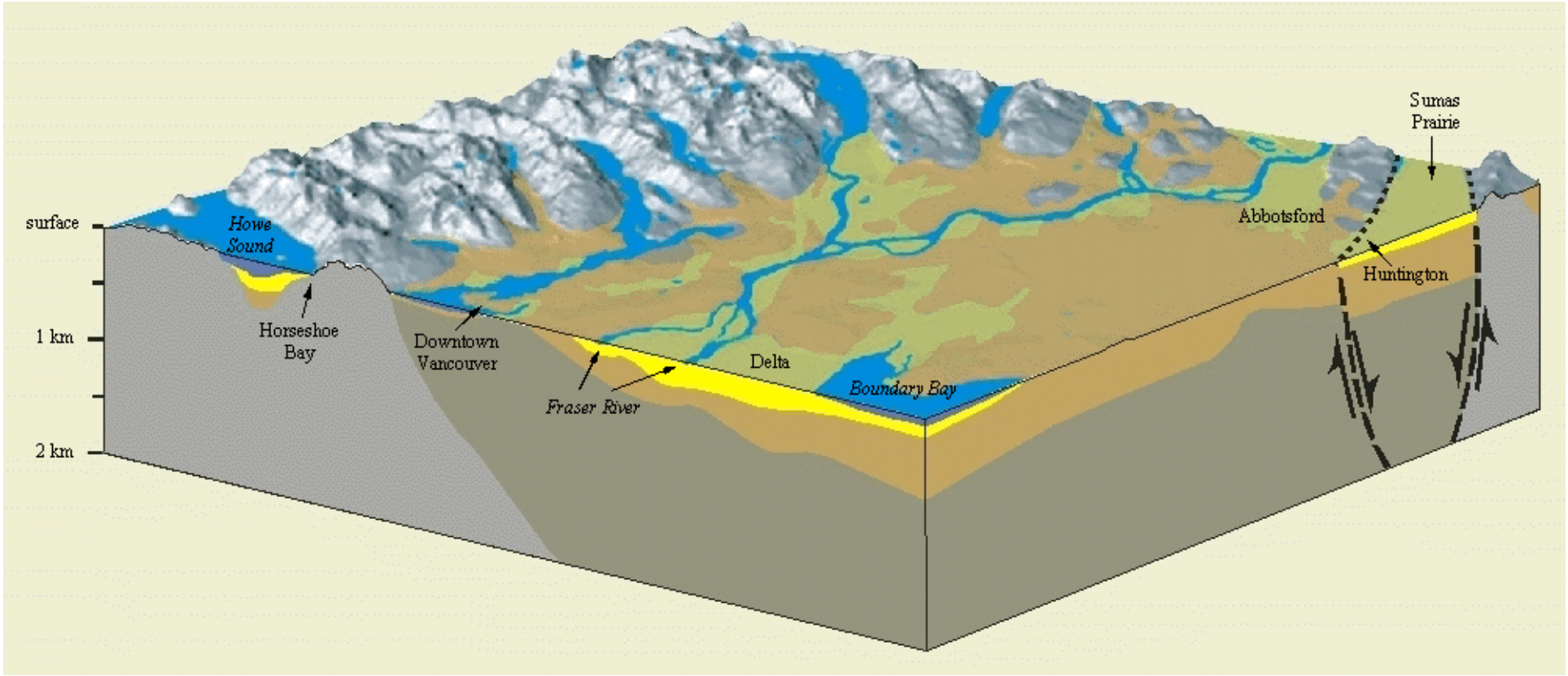
- What do you think will happen if we do the same thing and the soil is has water in it?

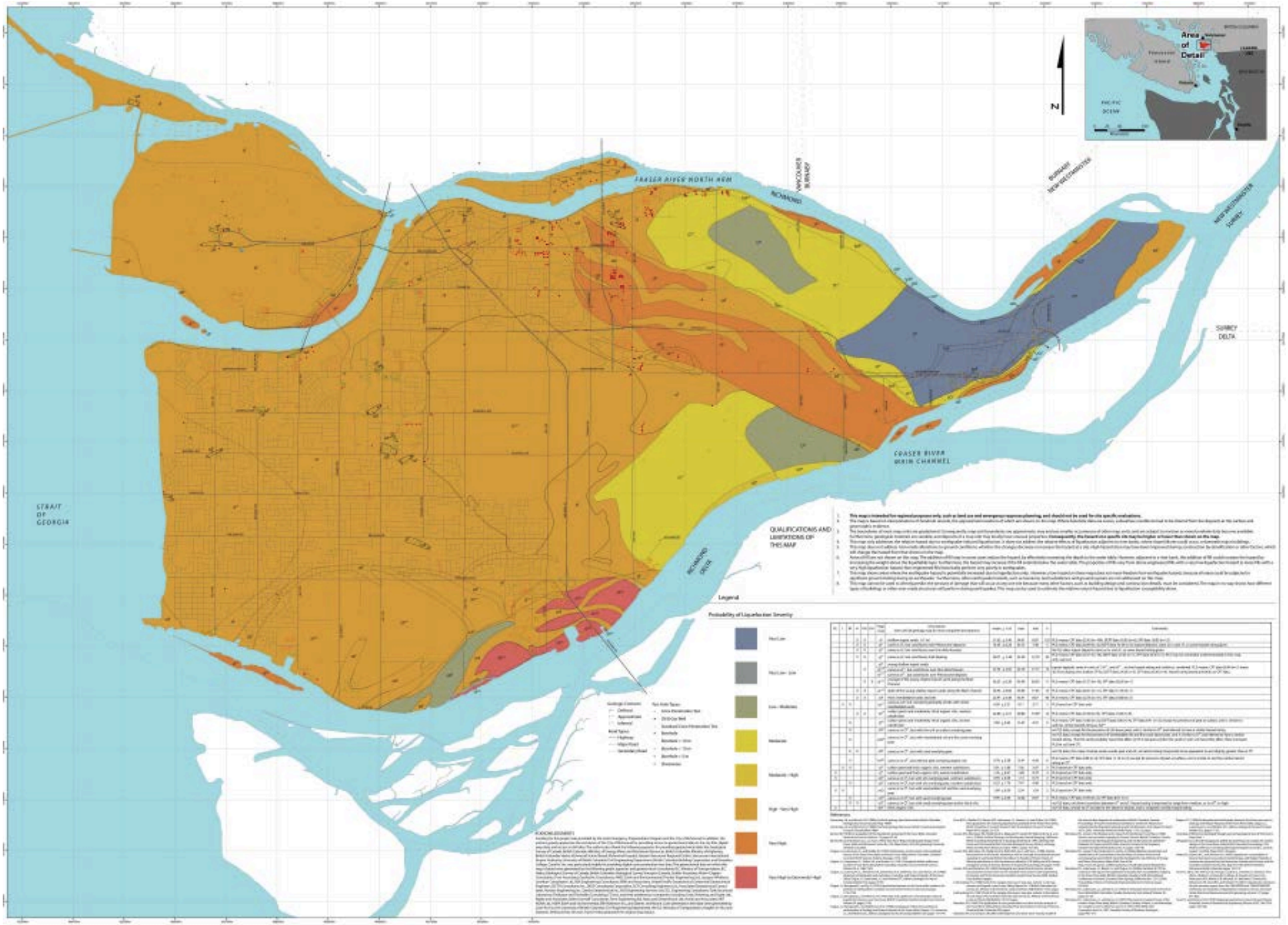
Liquefaction

- **Liquefaction** in Richmond, Delta, Pitt Meadows and parts of Port Coquitlam
- Occurs in water filled soils, that when shaken becomes weak and unable to support buildings & other structures.

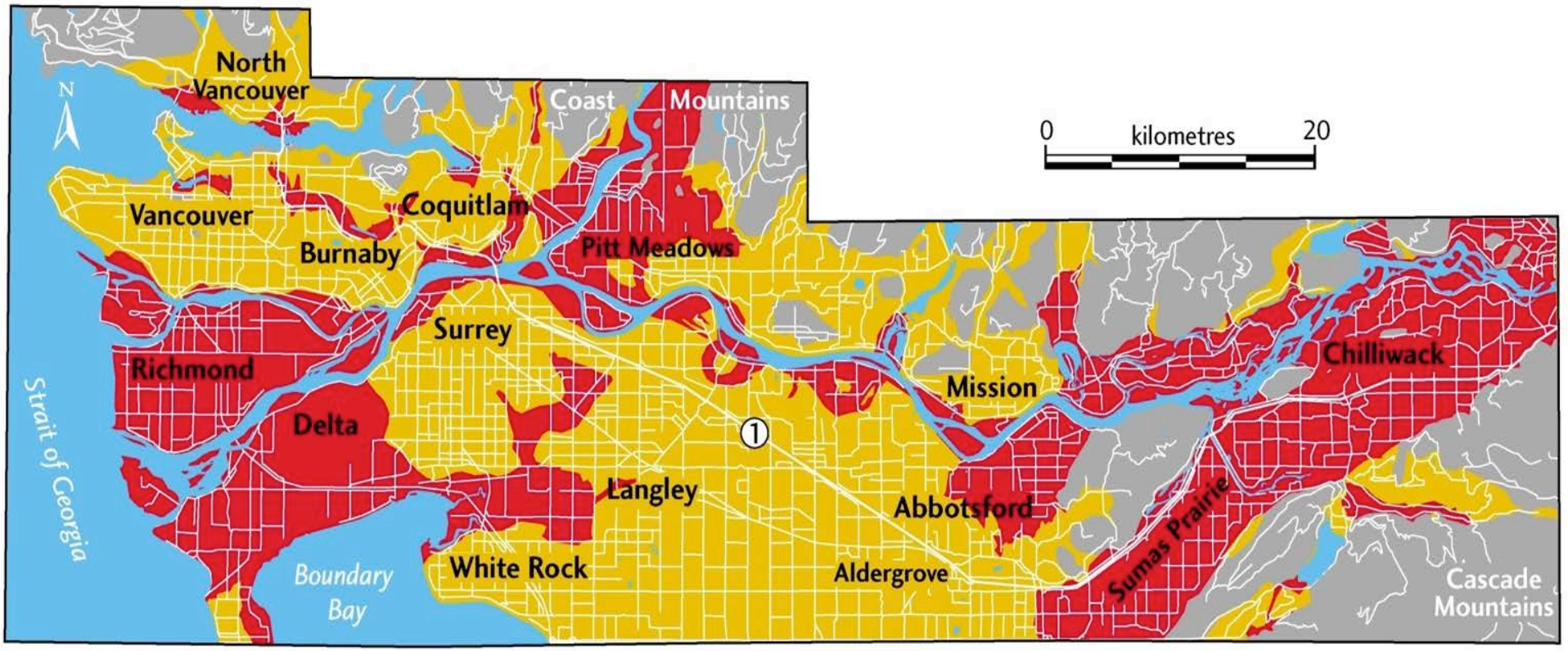


Source: Vancouver, City on the Edge


surface
1 km
2 km
Howe Sound
Horseshoe Bay
Downtown Vancouver
Fraser River
Delta
Boundary Bay
Abbotsford
Sumas Prairie
Huntington


Area of Detail
N
FRASER RIVER NORTH ARM
VANCOUVER
BURNABY
NEW WESTMINSTER
RICHMOND
SURREY
DELTA
FRASER RIVER
MAIN CHANNEL
STRAIT OF GEORGIA
QUALIFICATIONS AND LIMITATIONS OF THIS MAP
Legend
Probability of Liquefaction Severity
Very Low
Very Low - Low
Low - Moderate
Moderate
Moderate - High
High - Very High
Very High
Very High to Extremely High

How Safe Are You??



Source: Vancouver, City on the Edge

Liquefaction damage in Niigata, Japan. Buildings sink and then topple over.

On the morning of January 17, 1995, a 6.9 earthquake occurred near Kobe, Japan, killing 5,480 people and causing $150 billion in damage. The worst destruction ran along a previously undetected fault. Image courtesy of Dr. Roger Hutchison.

http://solidearth.jpl.nasa.gov/PAGES/quake01.html

Walking on Broken Glass

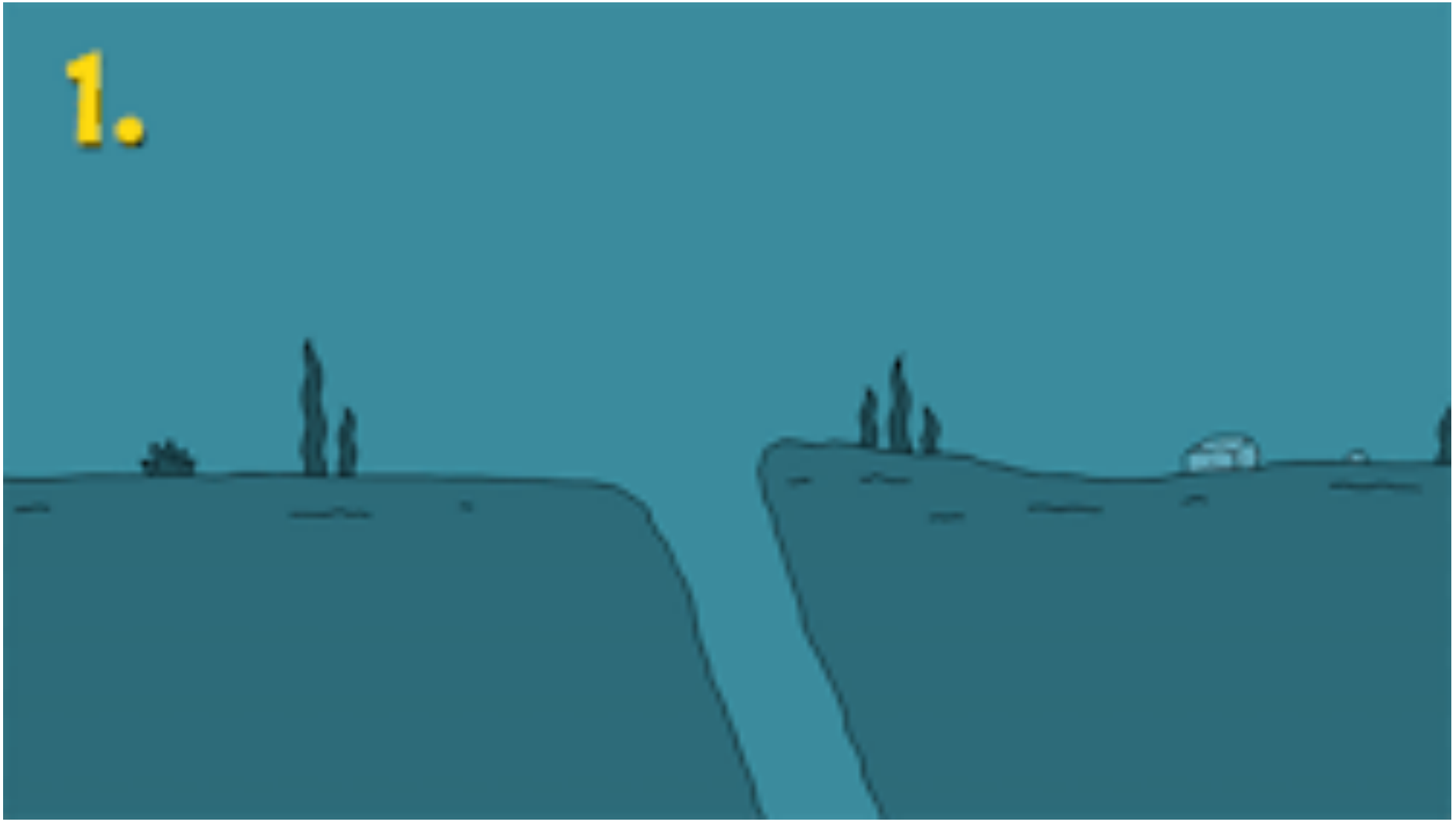
Scientists estimate that there would be over **a meter** of broken glass on the sidewalks of downtown Vancouver after a large earthquake.

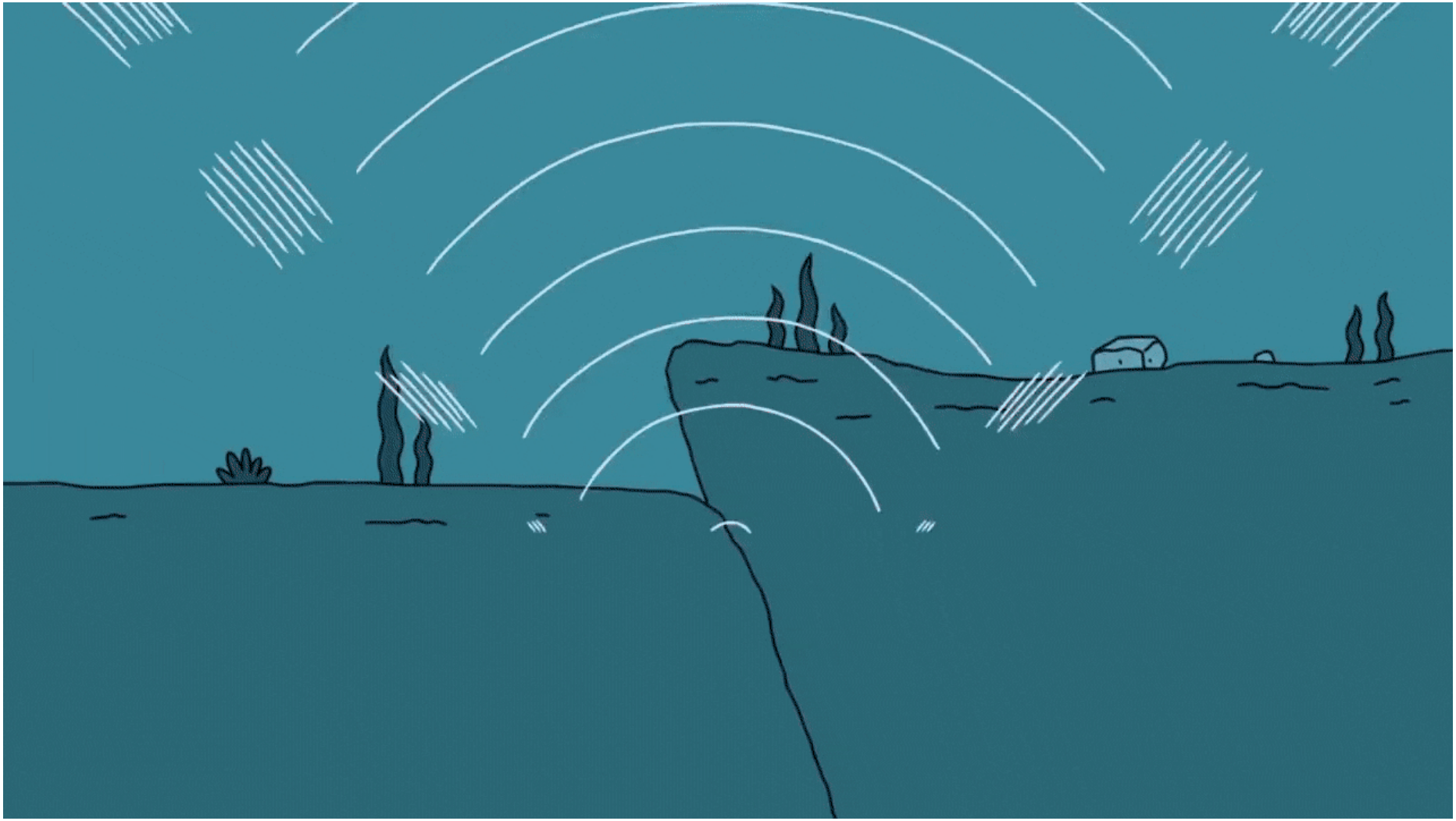
Can you think of some other negative effects of earthquakes?

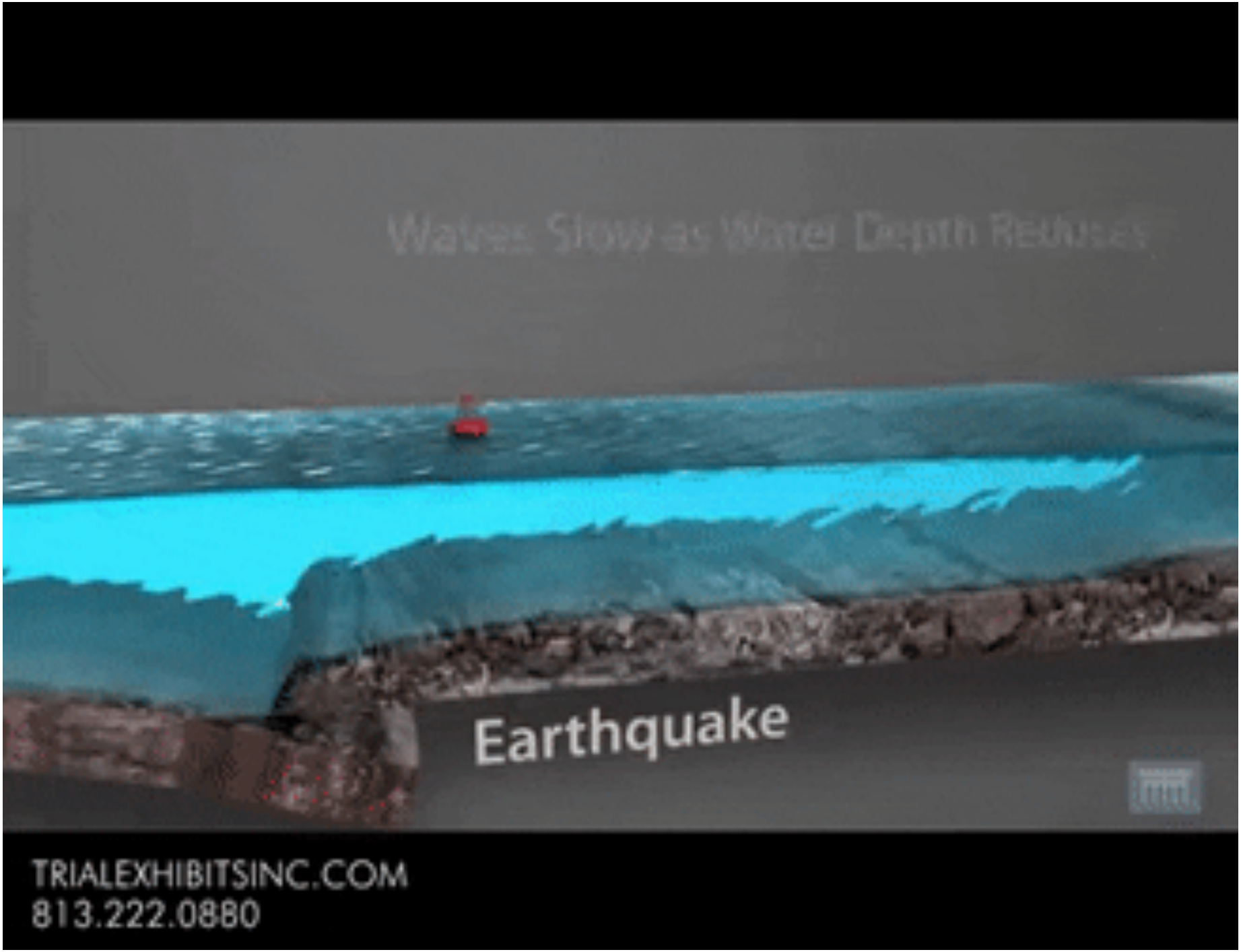
- **Landslides / Debris flows / avalanches**
- **Dam failure**
- **Tsunamis** – the devastating tsunami in the Indian Ocean in 2004 that killed over 283,000 people was caused by an offshore quake measuring over 9 mag..

Photo: USA Today.com

Tsunamis: A closer look






Waves Slow as Water Depth Reduces
Earthquake
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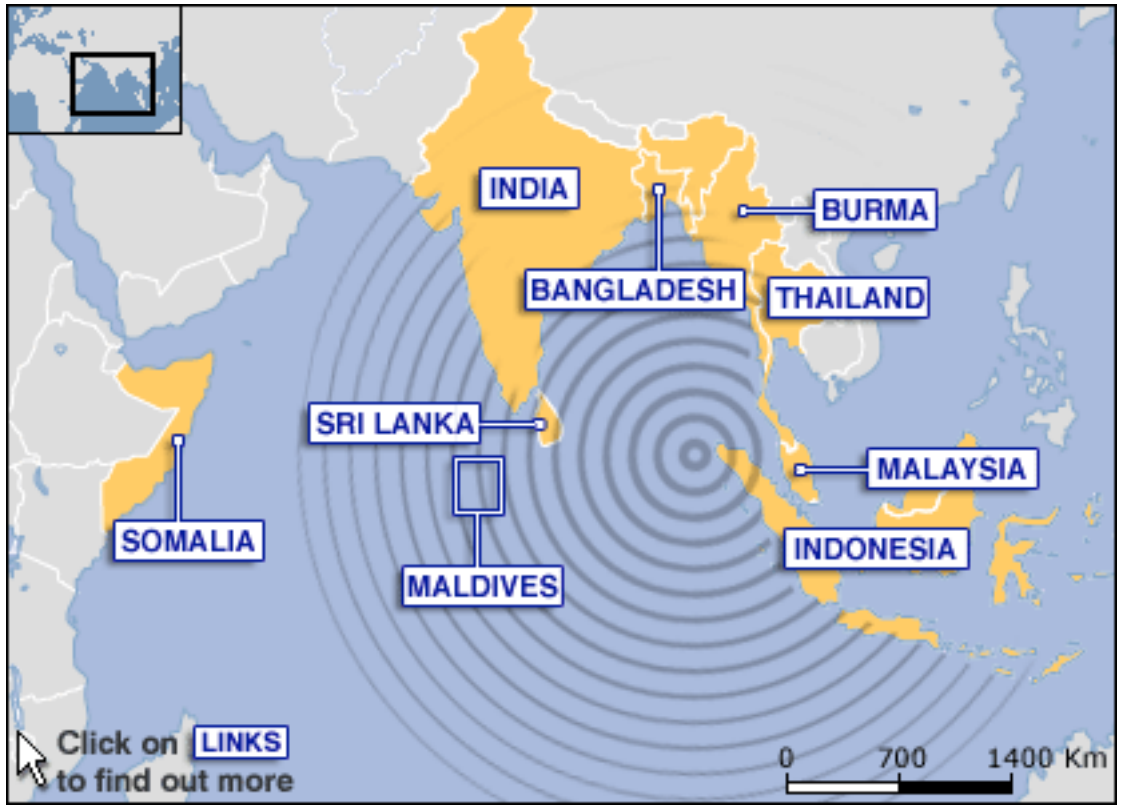
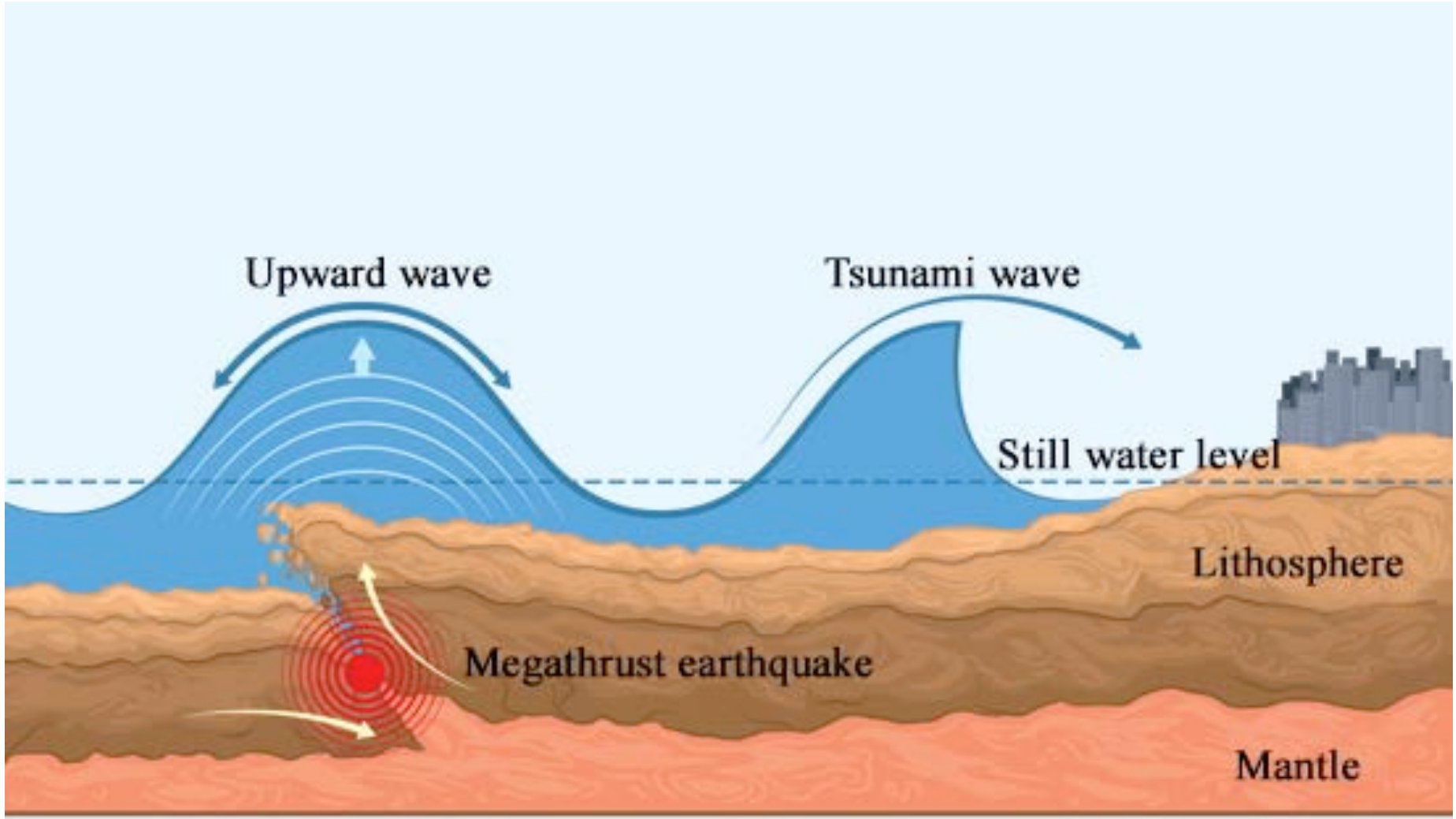
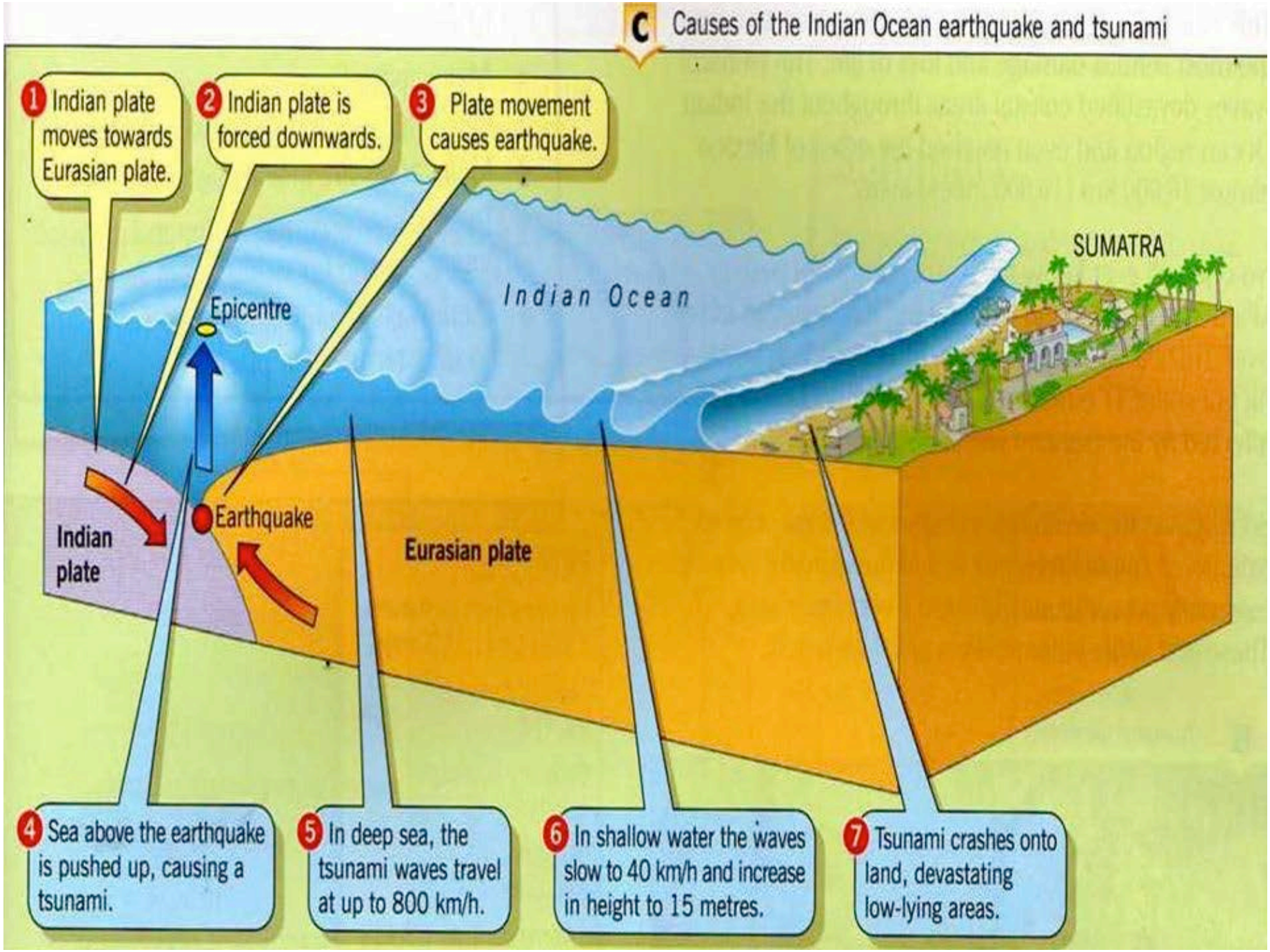
2004: Indian Ocean Tsunami

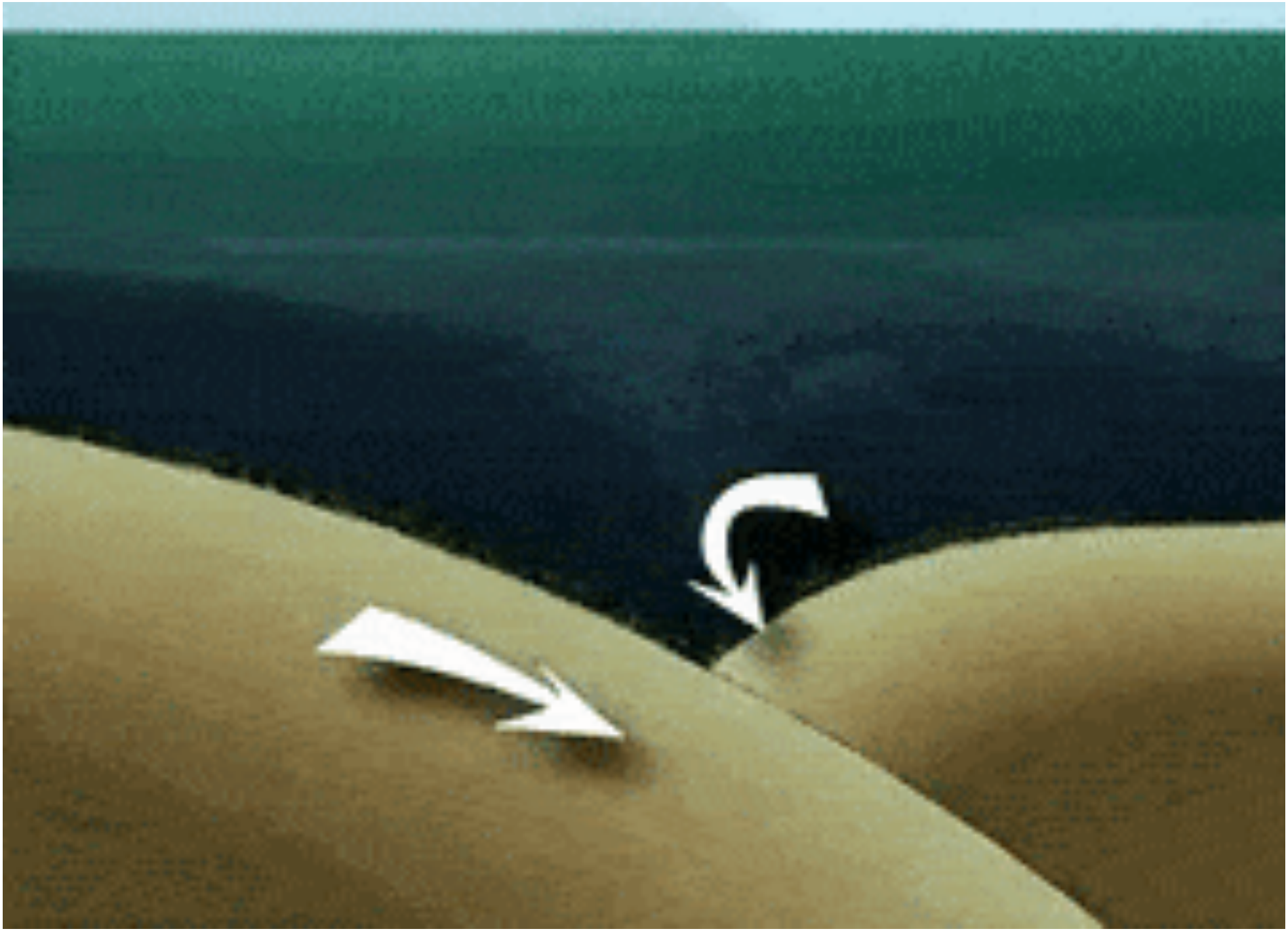
280, 000 people were killed

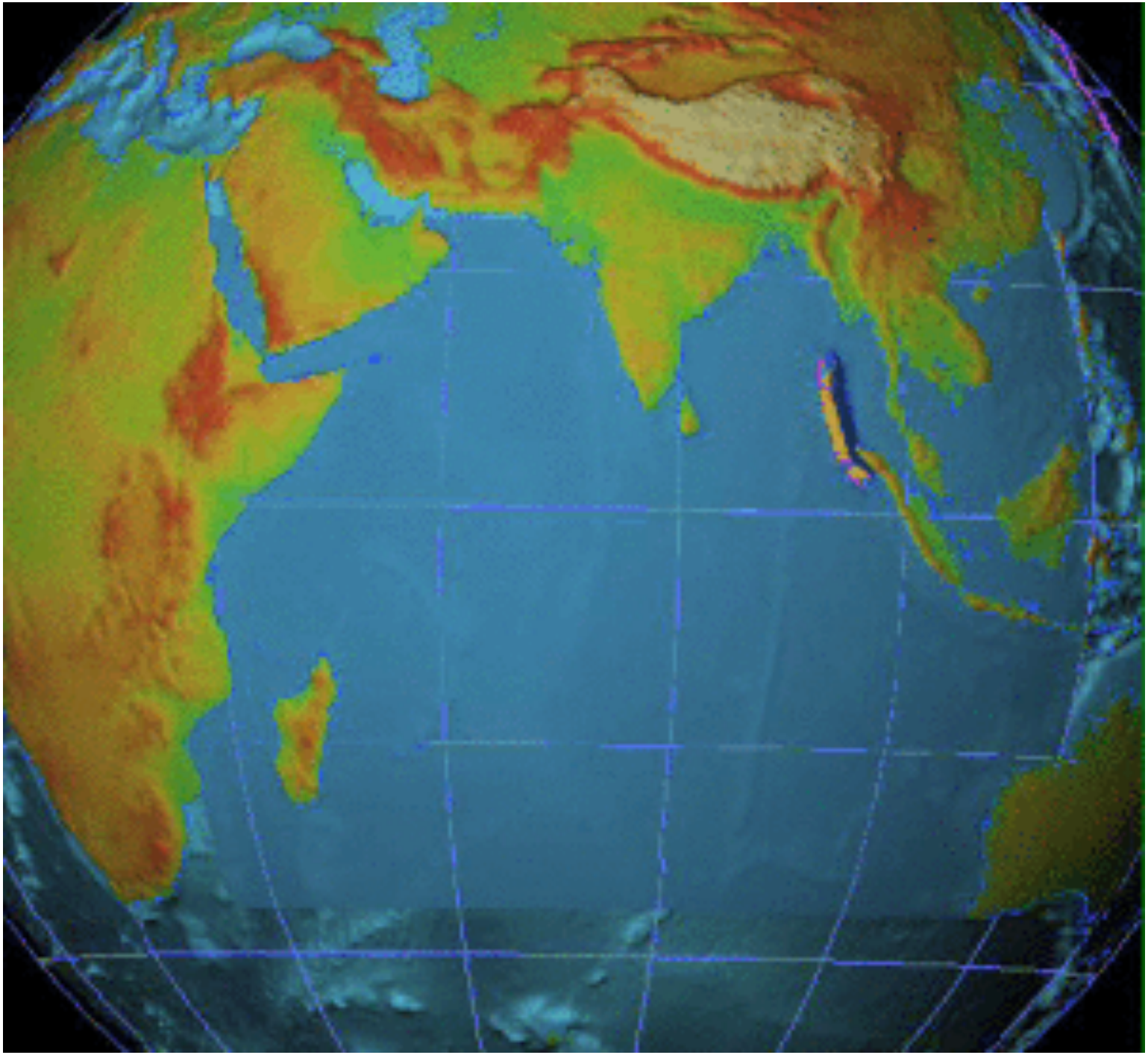




Formation of the Indian Ocean Tsunami

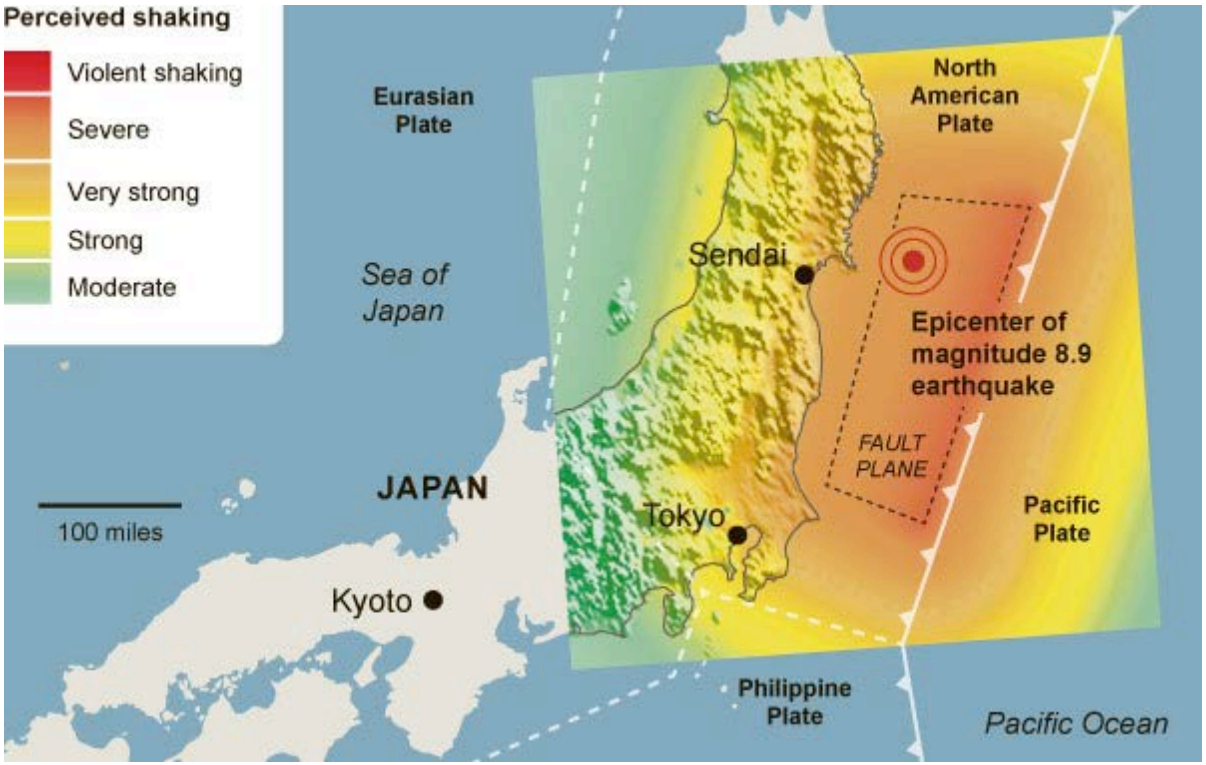

C Causes of the Indian Ocean earthquake and tsunami
1 Indian plate moves towards Eurasian plate.
2 Indian plate is forced downwards.
3 Plate movement causes earthquake.
SUMATRA
Indian Ocean
Epicentre
Earthquake
Indian plate
Eurasian plate
4 Sea above the earthquake is pushed up, causing a tsunami.
5 In deep sea, the tsunami waves travel at up to 800 km/h.
6 In shallow water the waves slow to 40 km/h and increase in height to 15 metres.
7 Tsunami crashes onto land, devastating low-lying areas.

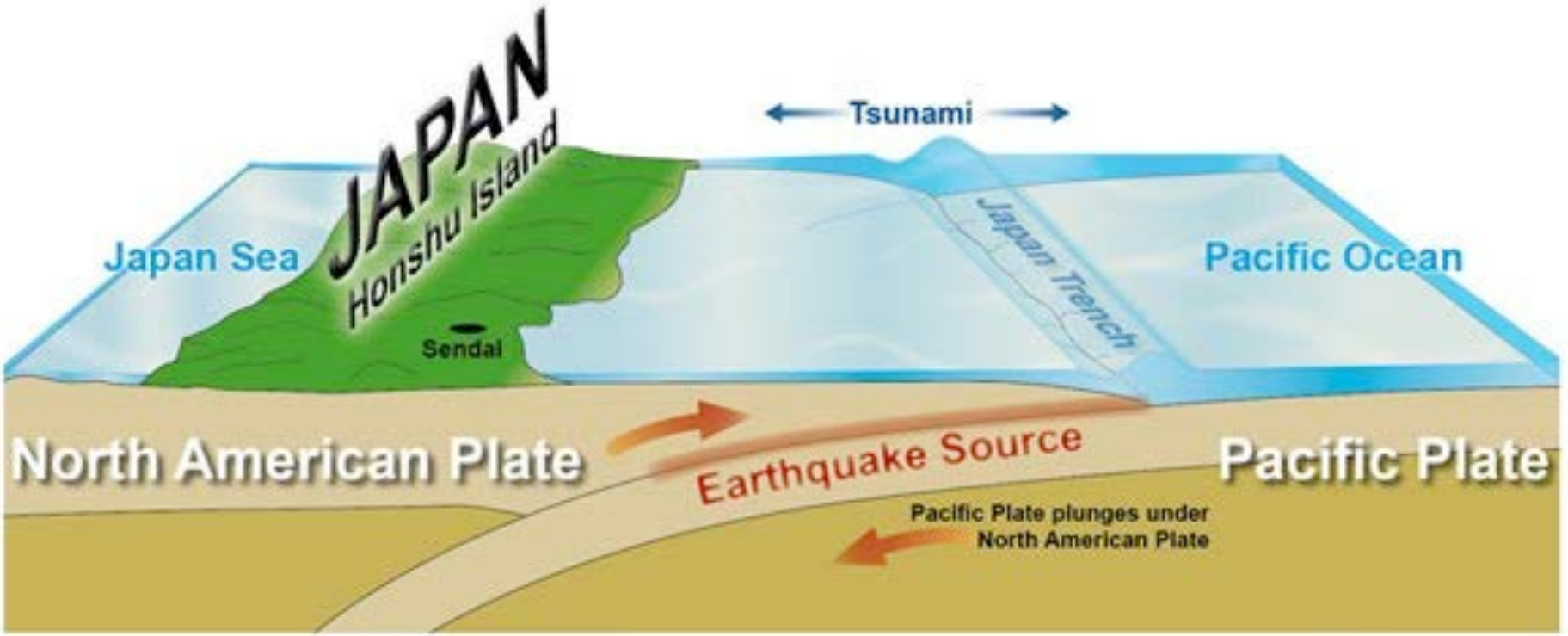




2011: Japanese Tsunami

- 15, 896 people died





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Are You Prepared?

- **What kinds of things can you do to prepare?**
  - A family earthquake plan?
  - An emergency kit with food / water and supplies for a minimum of 3 days?
  - The knowledge of what to do during an earthquake?