

NPTEL ONLINE CERTIFICATION COURSES

# EARTHQUAKE SEISMOLOGY


**Dr. Mohit Agrawal**

**Department of Applied Geophysics , IIT(ISM) Dhanbad**


**Module 01 : Basic Seismological Theory, Waves on a String , Stress and Strain and seismic waves**

**Lecture 01: Background, Basics of Seismology**

# CONCEPTS COVERED

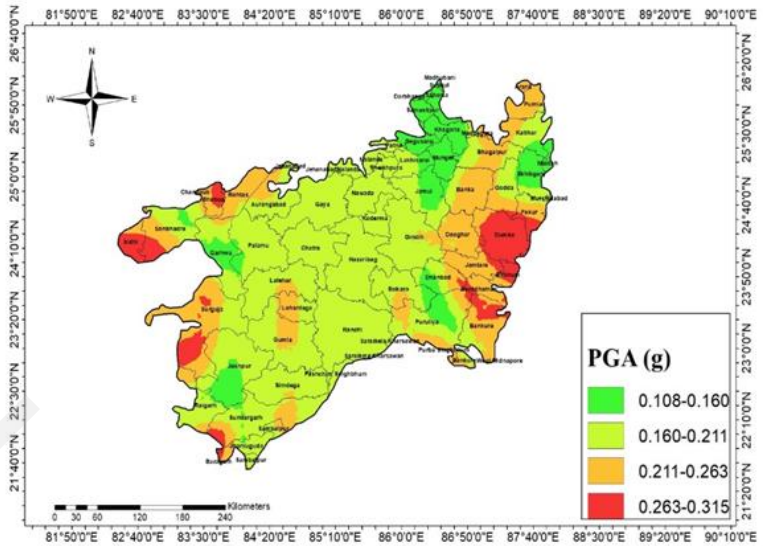
1. Introduction
2. Quick overview of the course
3. Various seismological sources
4. Major earthquakes in India, earthquake sources
5. Plate boundaries
6. World's hazard map

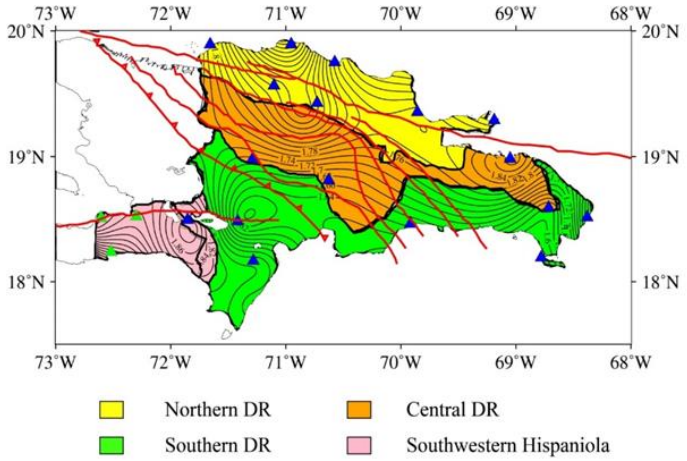
# Me

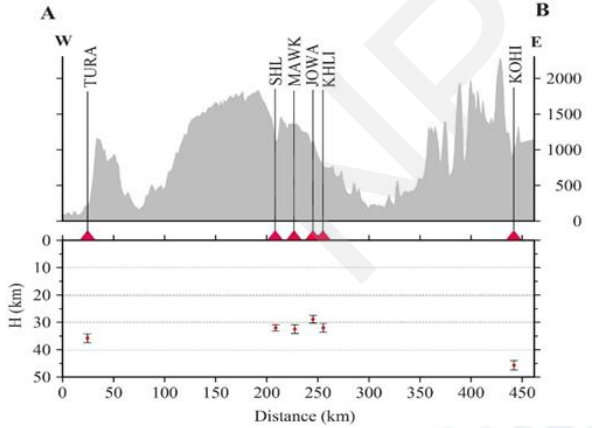
**PhD from Baylor University, USA !**

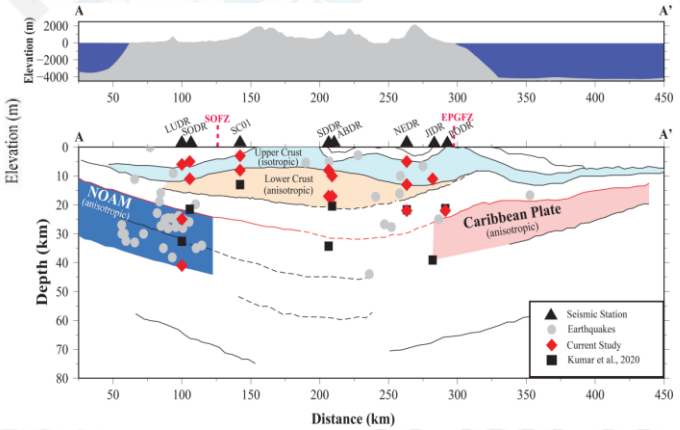
**Masters from IIT (ISM), Dhanbad !**

**Interests: Seismology, Tectonics evolution of the planet, Seismic Hazard.**



# Earthquakes!

I. Where do Earthquakes occur?

Plate tectonics and quakes

Tectonics, Stress and Faulting

I. Features of Earthquakes and Faults

Slip along fault

Types of Waves

Finding the Epicenter

Magnitude and Shaking

# Have you ever felt an earthquake?

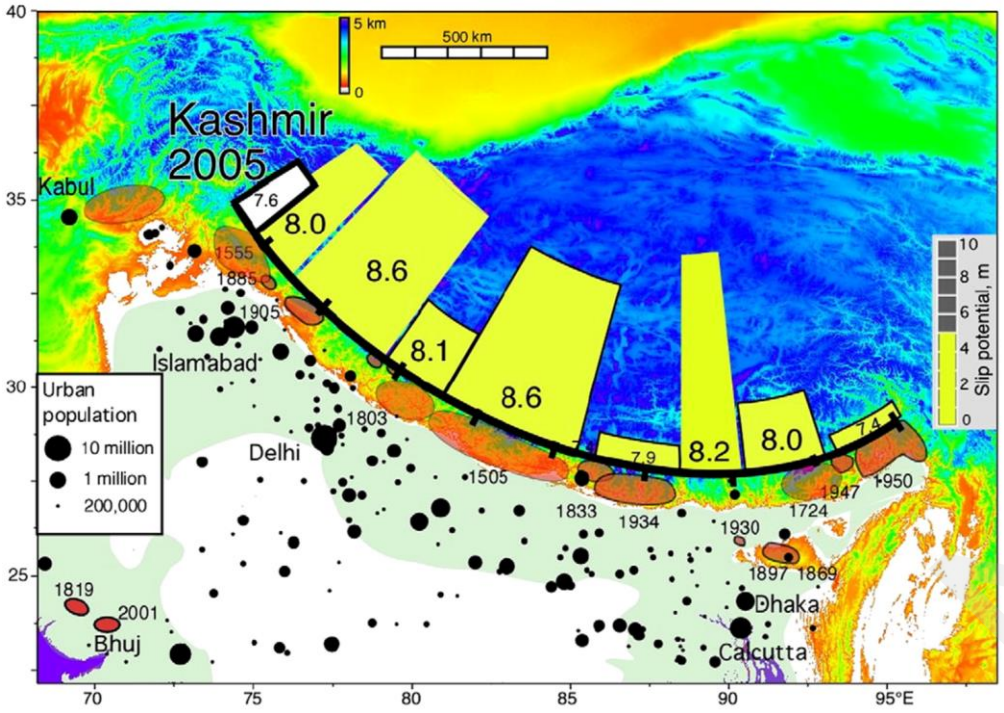
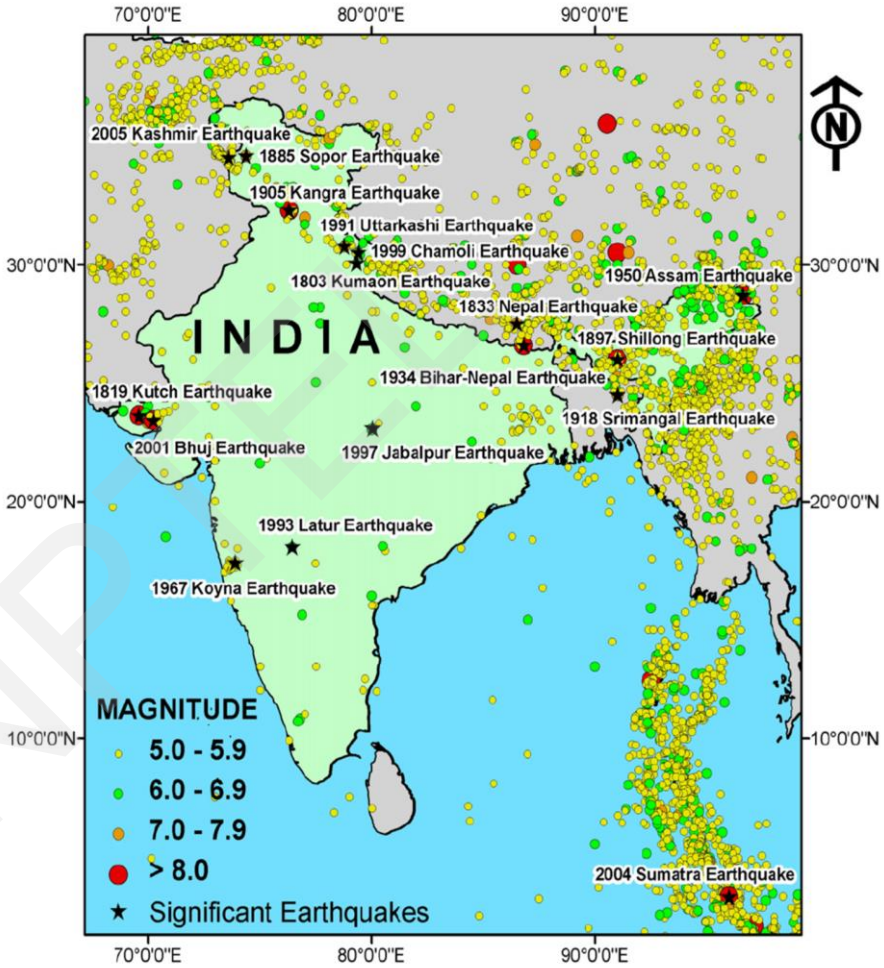



Fig. 6. The major earthquakes along the Himalayan Mountain belt (after Bilham et al., 2001).




(Walling and Mohanty 2009)

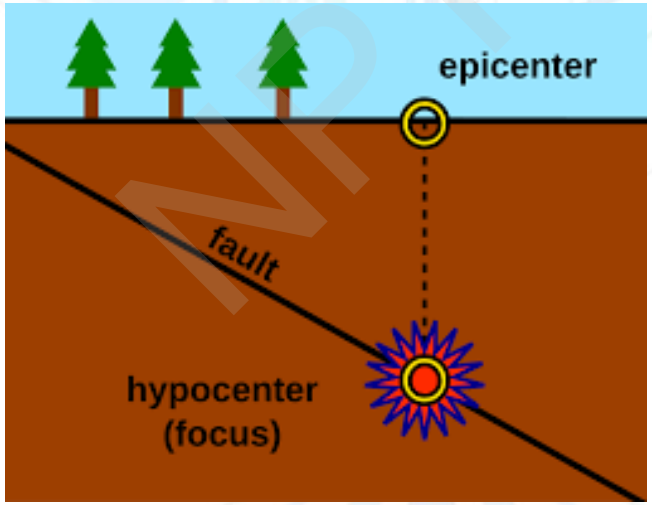
# What is an earthquake?

**An earthquake is a weak to violent shaking of the ground produced by the sudden movement of rock materials below the earth's surface.**

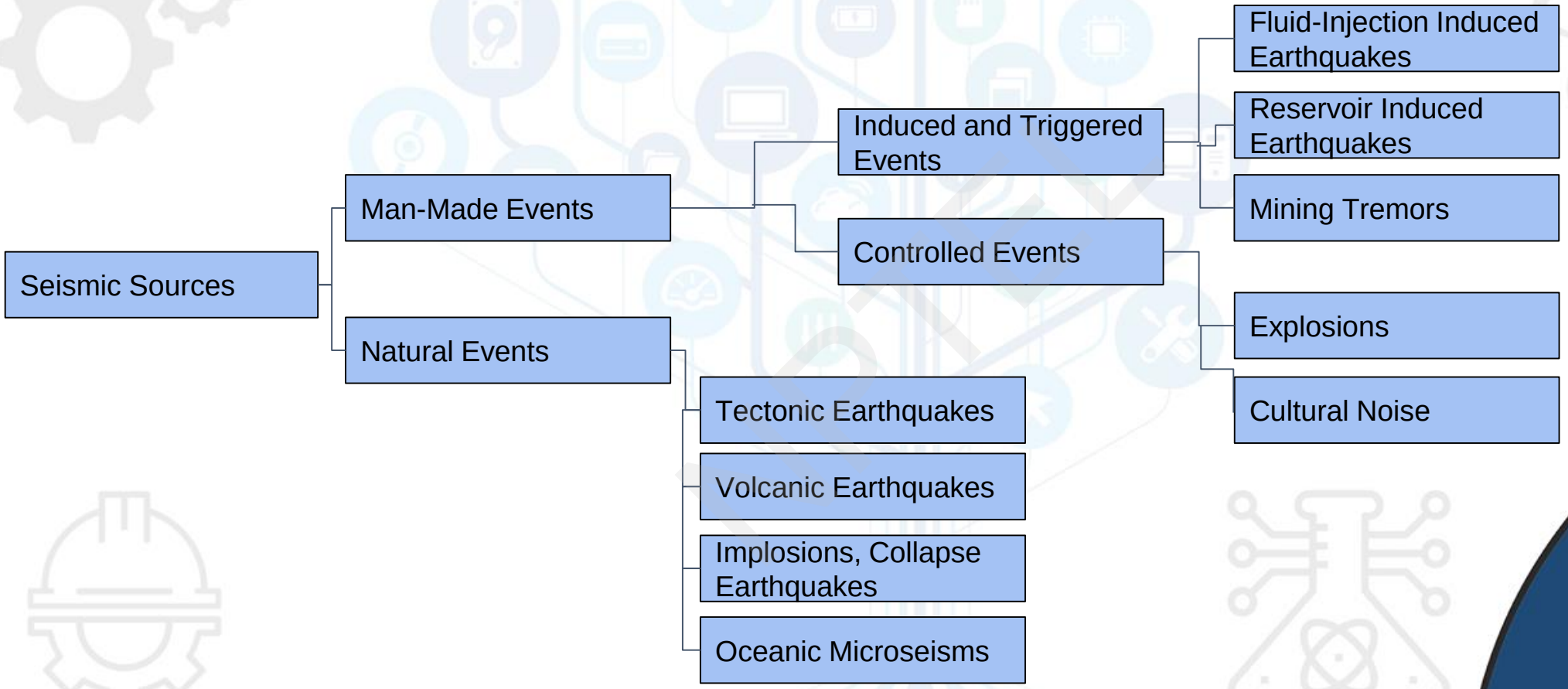
# Where does an earthquake originate?

**Focus is the point inside the earth where an earthquake begins. It is also known as hypocenter.**

**Epicenter is the point on the surface of the earth directly above the focus.**



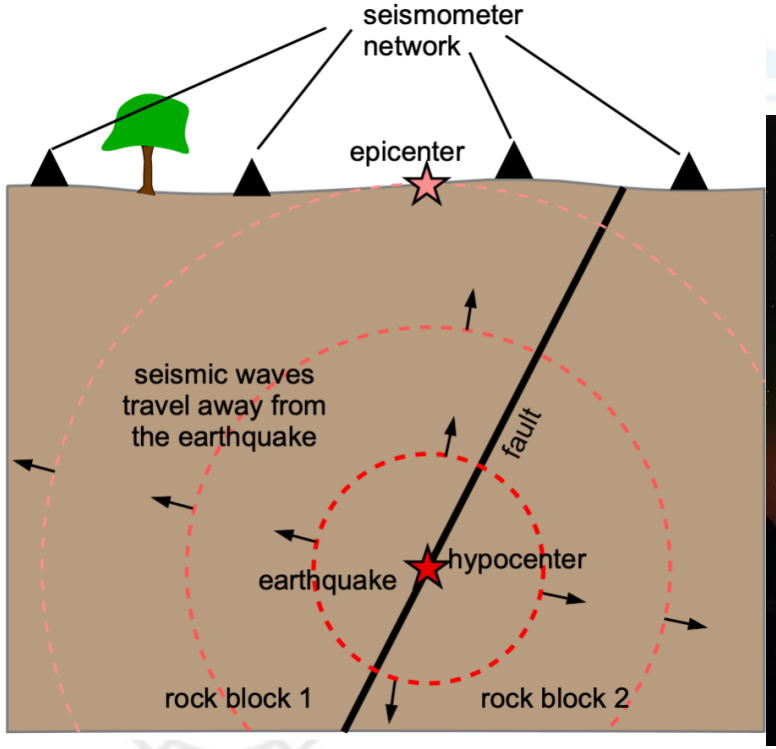
# What are seismological sources?



# Basics Of Seismology

## What are seismological sources?

### Natural Sources




Earthquake, Volcano, and tidal waves (Tsunami)

# Basics Of Seismology

## What are seismological sources?

### Man-Made Sources

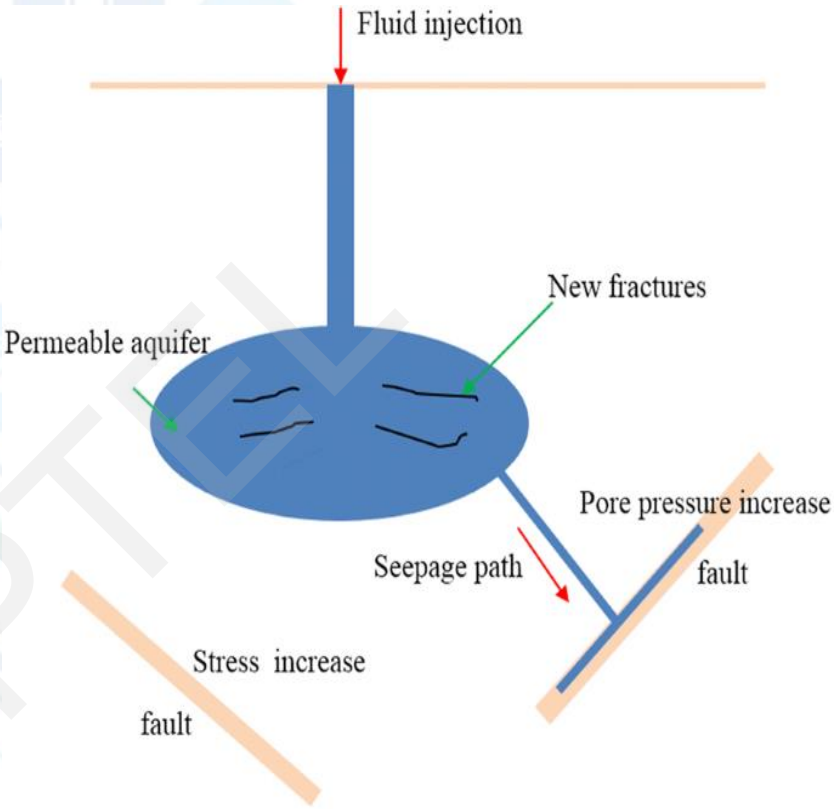


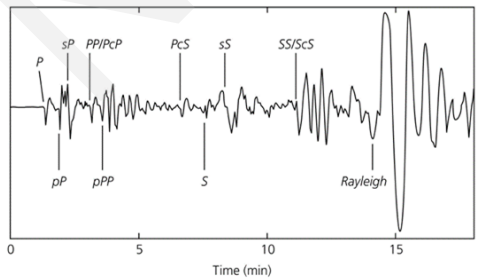

**Fig. 1.3 Induced Seismicity: Explosion, and fluid injection.**

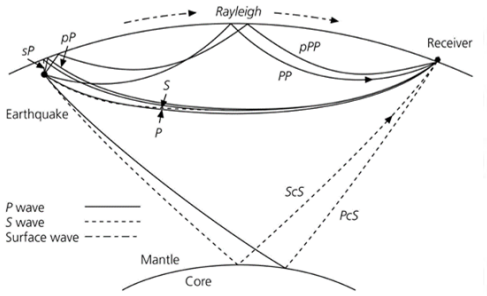
# What is seismology?

- The study of anything related to seismic (elastic waves), such as:

a. Energy Creation (earthquakes and faulting, nuclear tests, volcanic erruptions, mine collapses)
b. Energy transmission
- Inferring the structure of the medium through which seismic waves travel (Inverse theory)
- energy propagation and absorption
- scattering

- The word “seismo” originates from the Greek language, which means earthquake or vibration, and “logos” means science.
- Energy recording
- Seismometers
- Energy recording
- seismometers
- Seismic Hazards



# What does a seismologist do?

- Seismologist is a person, who listens to the sounds of the Earth, analyse them and makes inferences from them.

- Seismology is not only limited to the planet Earth, but its concept is equally applicable to other celestial bodies, which most commonly includes seismology of the moon, i.e., lunar seismology; seismology of Mars: Mars seismology and seismology of sun, i.e., helioseismology

- As a seismologist, we record a fundamental quantity of physics, i.e., the arrival time of seismic waves passing through the different chunks of the Earth.

# Seismic instrumentation

**Below we see two modern broadband (in frequency) seismometers that record ground motion (Trillium Compact 120s on the left, and a Guralp-3T on the right).**


# Glimpses of Our Recent Installations (Broadband Seismometers)

Nirsa (Jharkhand)

Deoghar (Jharkhand)

Peterbar (Jharkhand)

Jowai (Meghalaya)

Khlieriat (Meghalaya)

Mawryngkneng (Meghalaya)

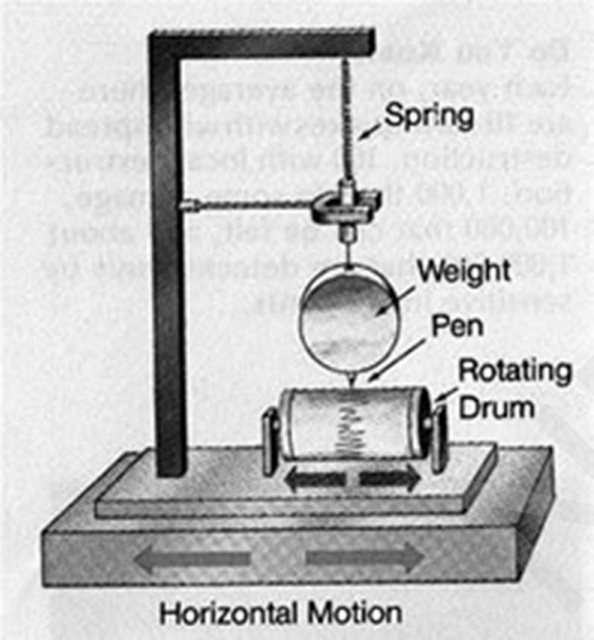
# Basics Of Seismology

What is the difference?

Seismometer

Seismograph

Seismogram



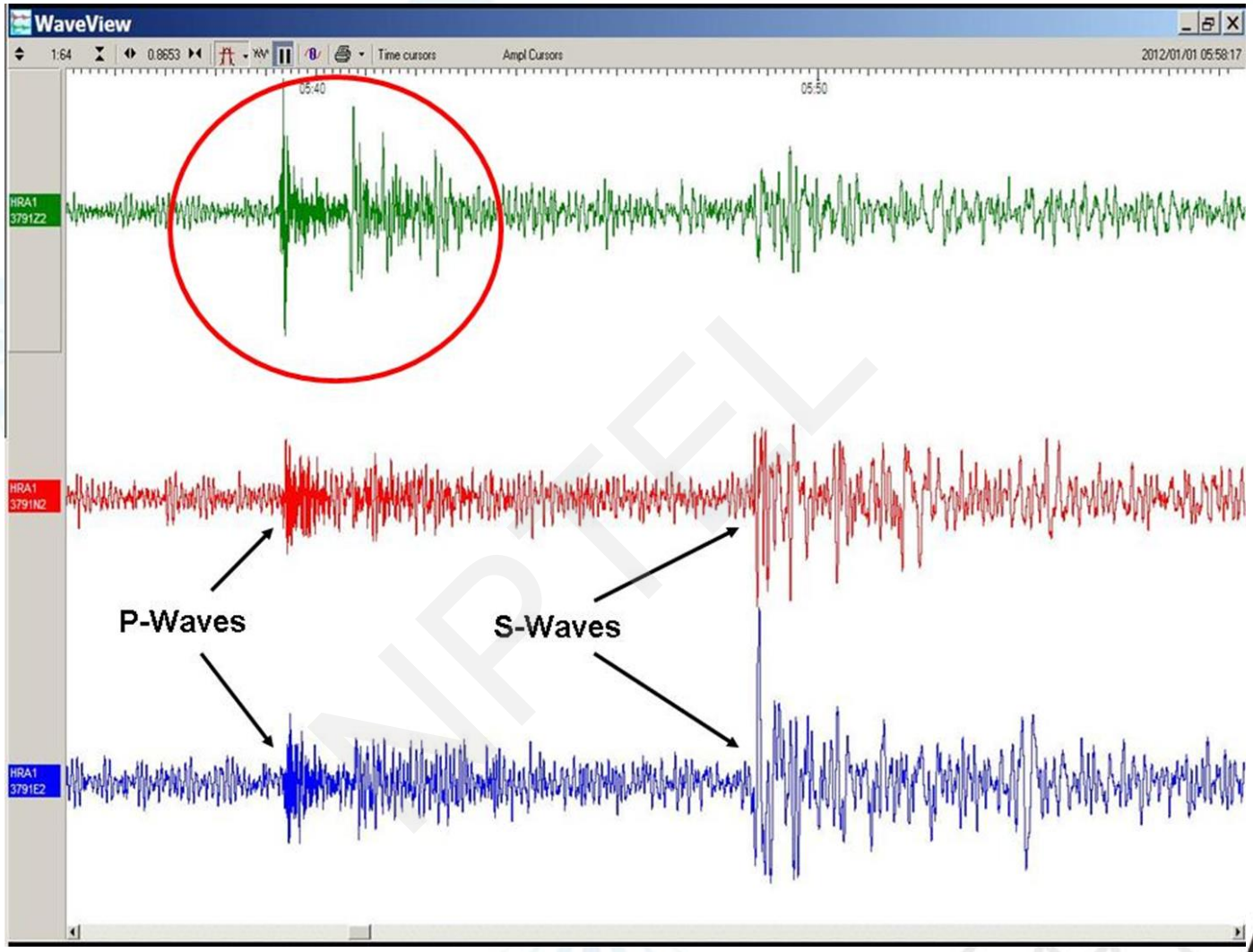

## What does a seismologist measure??

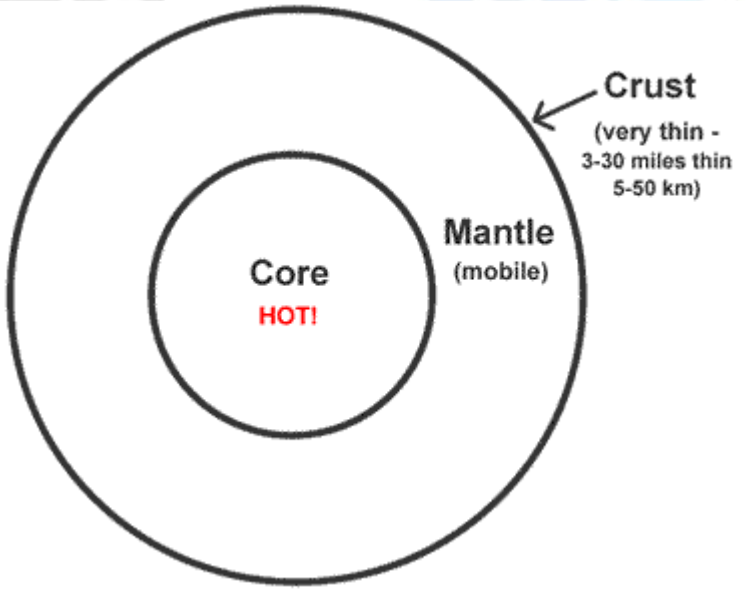
- Measure three-dimensional ground vibrations either in the form of displacement, velocity, or acceleration.

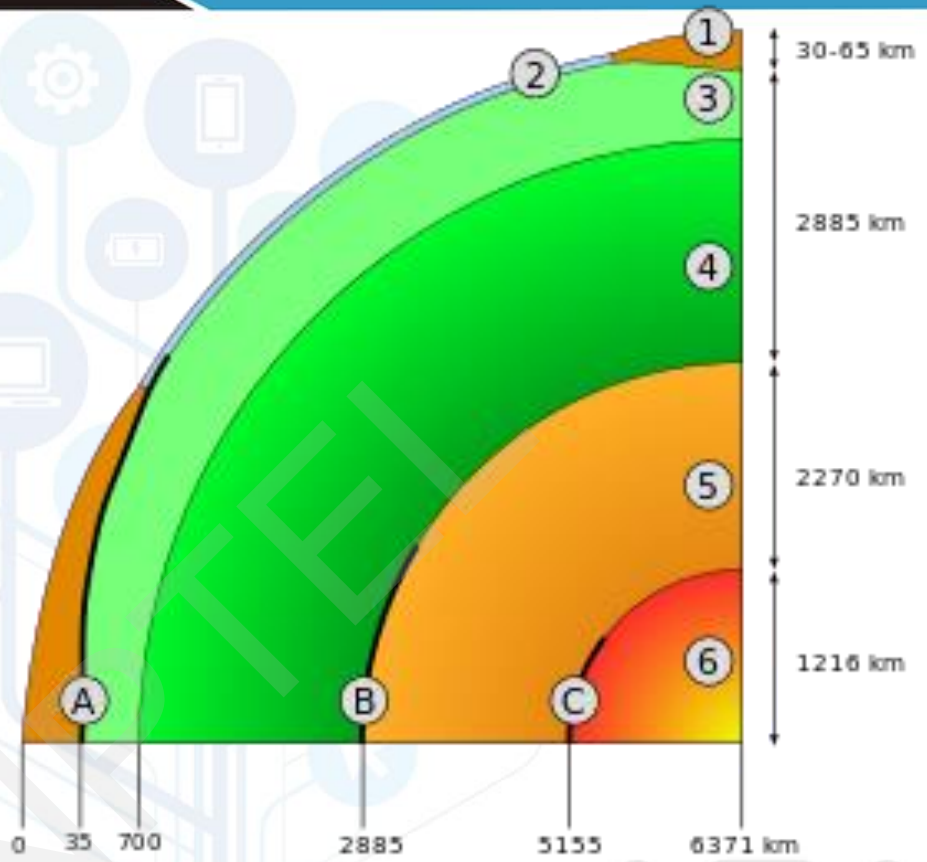
- For this purpose, we install a highly sensitive sophisticated measuring device, generally at a very quiet place known as a seismograph.

# What is a seismogram?

This is an example of a 3D ground velocity caused by an earthquake. Here, the green colour shows the vertical component, and for the rest of two, red represents the NS component, and cyan displays the EW component.

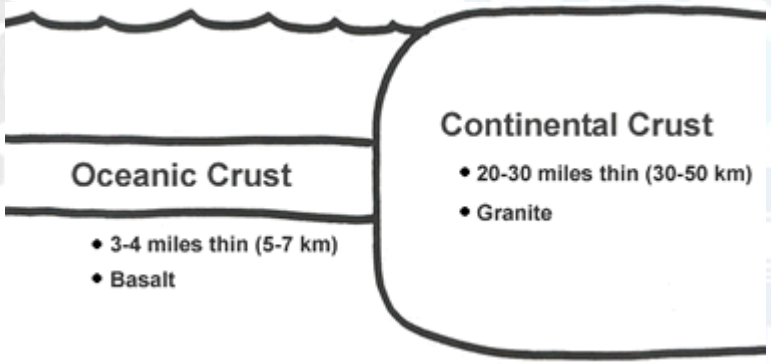


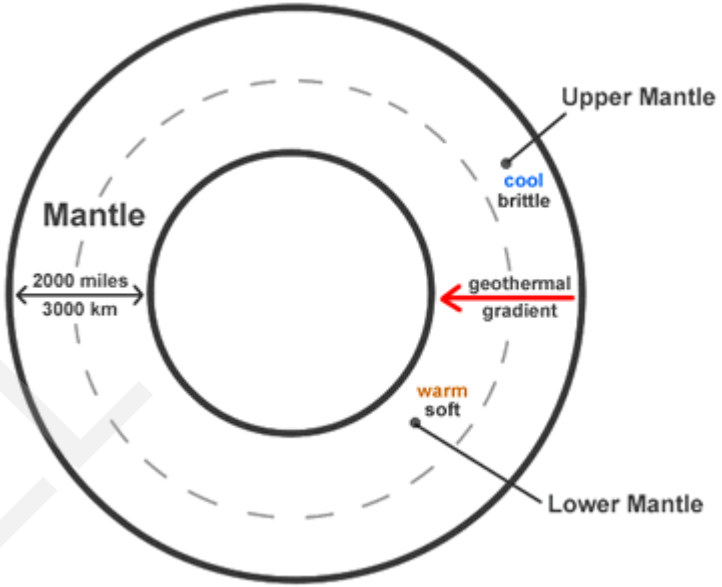


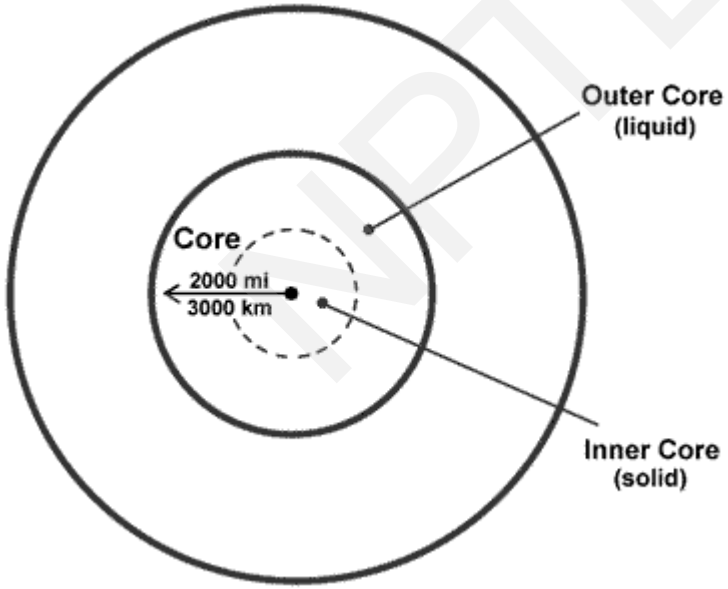




**Schematic view of the interior of Earth. 1. continental crust – 2. oceanic crust – 3. upper mantle – 4. lower mantle – 5. outer core – 6. inner core**

**A: Mohorovicic discontinuity – B: Gutenberg discontinuity– C: Lehmann Bullen discontinuity.**


Oceanic Crust
• 3-4 miles thin (5-7 km)
• Basalt
Continental Crust
• 20-30 miles thin (30-50 km)
• Granite

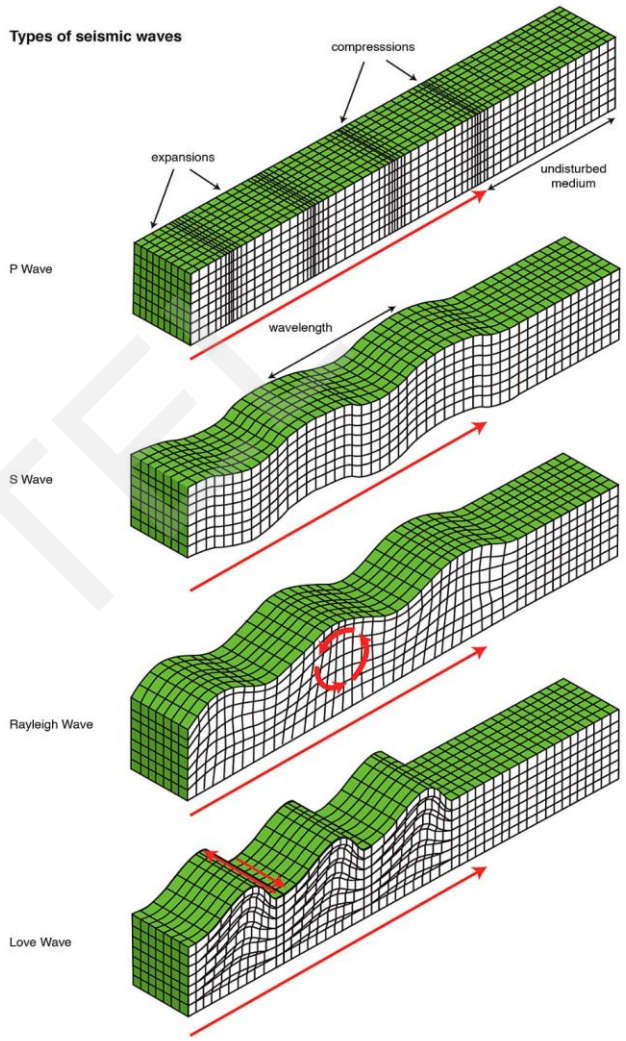

Upper Mantle
cool
brittle
Mantle
2000 miles
3000 km
geothermal
gradient
warm
soft
Lower Mantle


Outer Core
(liquid)
Core
2000 mi
3000 km
Inner Core
(solid)

Released stress at the location of the source, travels in the form of deformation known as seismic waves.

- Body waves (P-and S-waves)

- Surface wave (Rayleigh and Love waves)

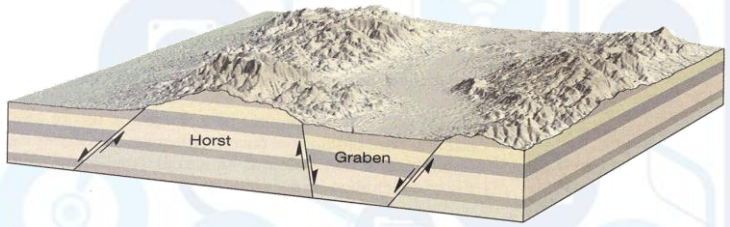


| Primary Waves | Secondary Waves |
|---|---|
| P-waves | S-waves |
| Primary Waves | Secondary waves |
| Compressional Waves | Shear Waves |
| Travels through solid, liquid and gas | Travels through solid only |
| Particle motion along the direction of propagation | Particles motion perpendicular to travel direction because shear modulus is zero for liquid and gases |
| Longitudinal Waves | Transverse Waves |
| P-waves ~1.7 times faster than S-waves. | |

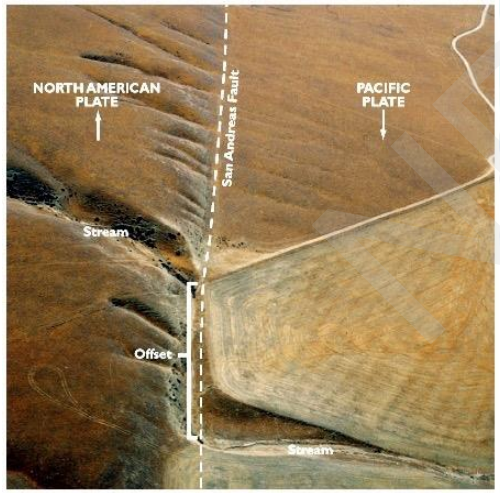
| Rayleigh Waves | Love Waves |
|---|---|
| Also called ground roll | Polarized shear waves (SH) waves |
| Travels in the form of ripples | Horizontal particle motion perpendicular to wave propagation |
| Existence predicted by Lord Rayleigh in 1885 | Named after A.E.H Love in 1911 |
| Retrograde elliptical motion | Slightly faster than Rayleigh waves and about 90% of S-wave velocity |

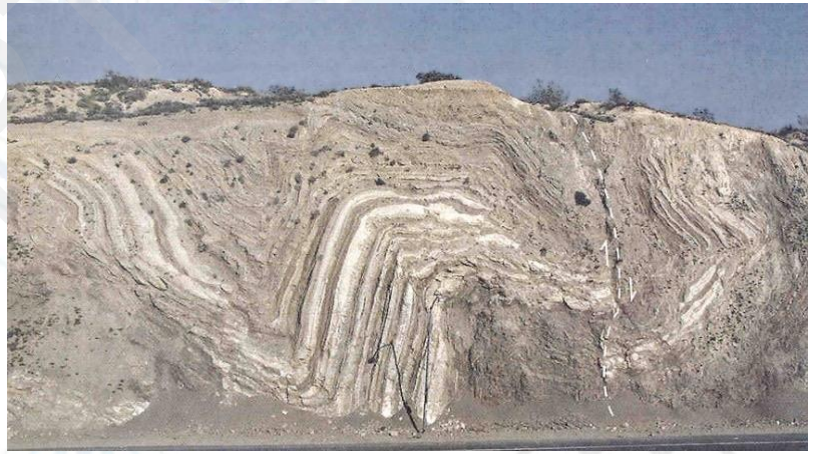
# Quick Course overview

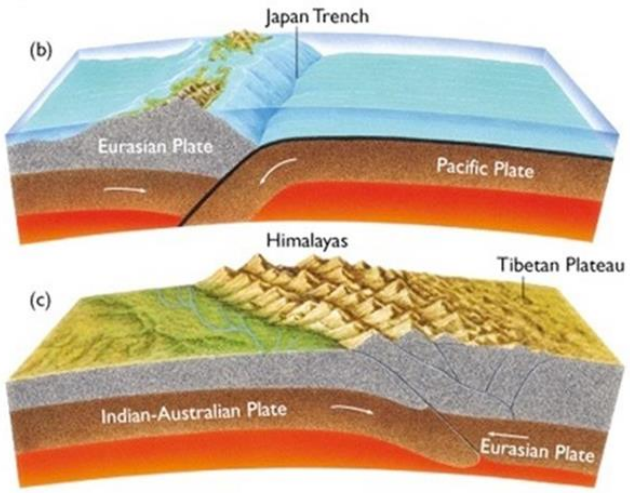
***Stress*** **(force on surface in a medium) produces** ***Strain*** **(resulting distortion/deformation.**

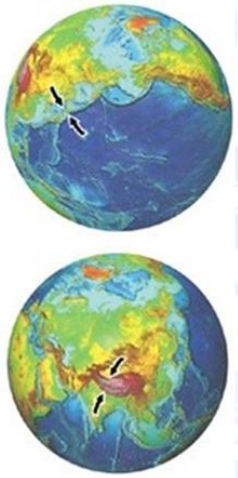



**Our first few weeks will be devoted to understanding the constituent equations that relate stress to strain and result in elastic wave propagation.**

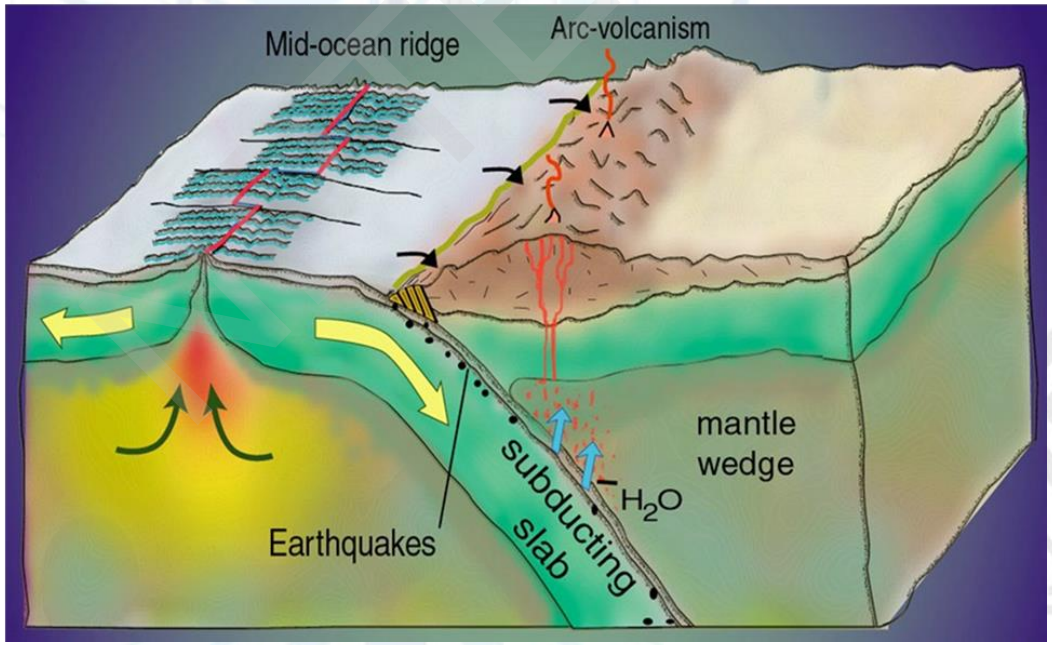


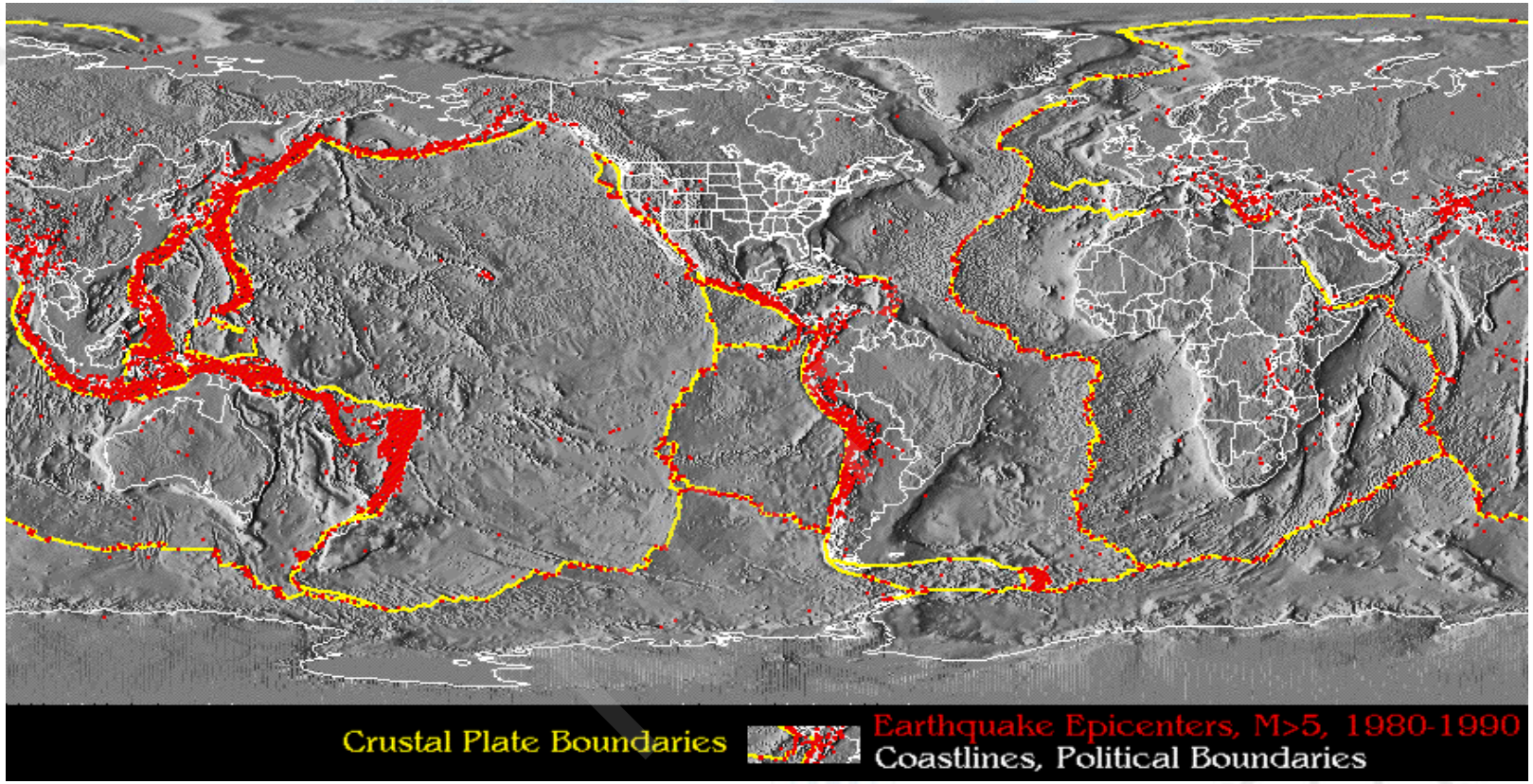


**Generally, earthquakes releases stress that accumulates along the plate boundaries.**

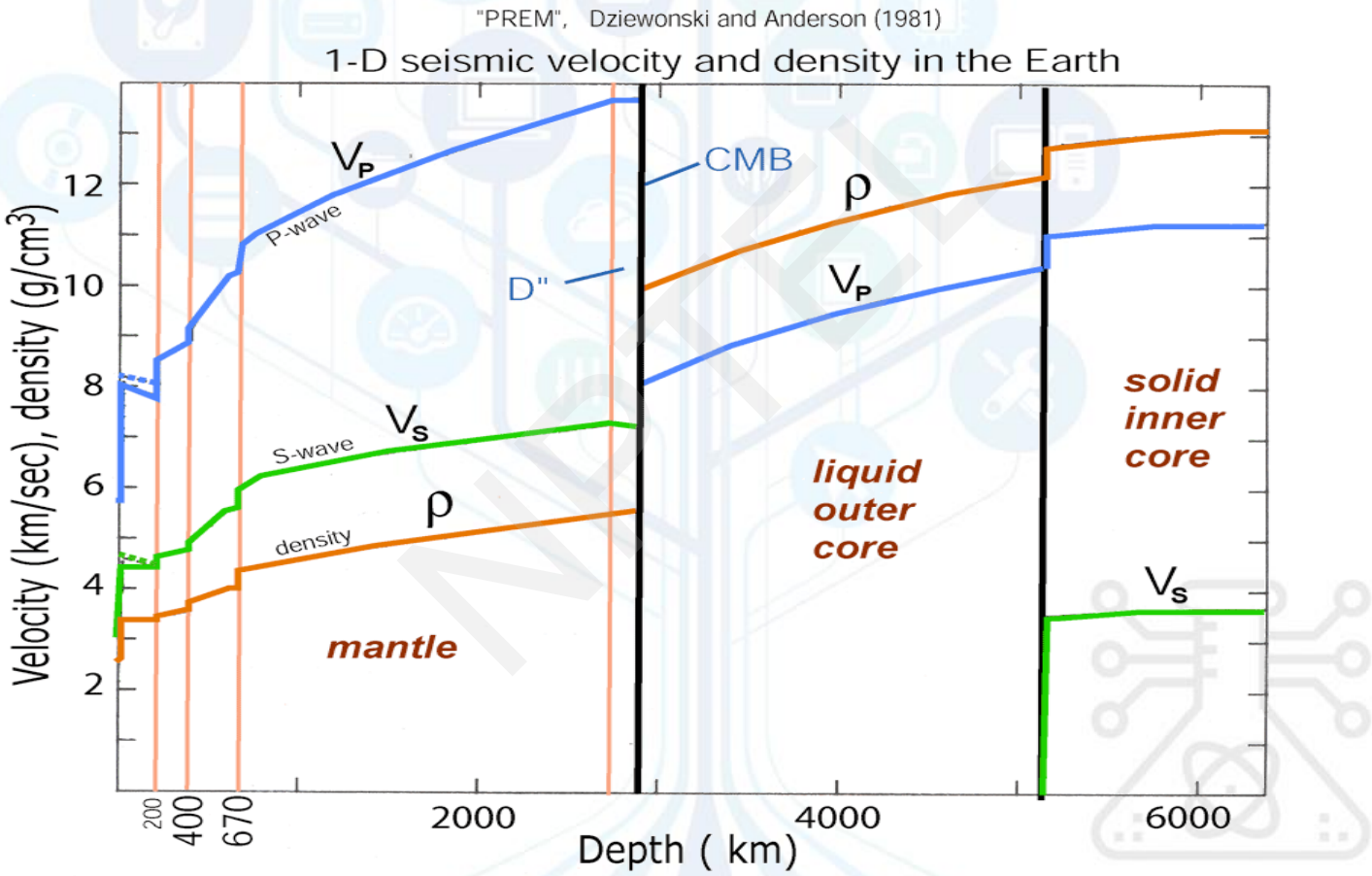


# Seismicity helps to define plate boundaries: (image from NDGC)




Map showing epicenters of earthquakes during 1980-1990. Most earthquakes occur along the boundaries between tectonic plates.

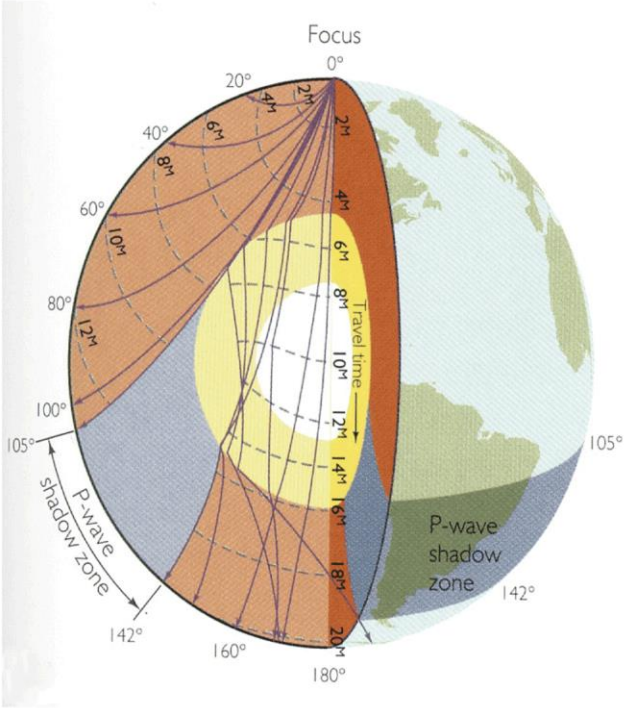
## We'll learn about the velocity and structure of the Earth, and how this affects seismic wave propagation (Chap. 3).

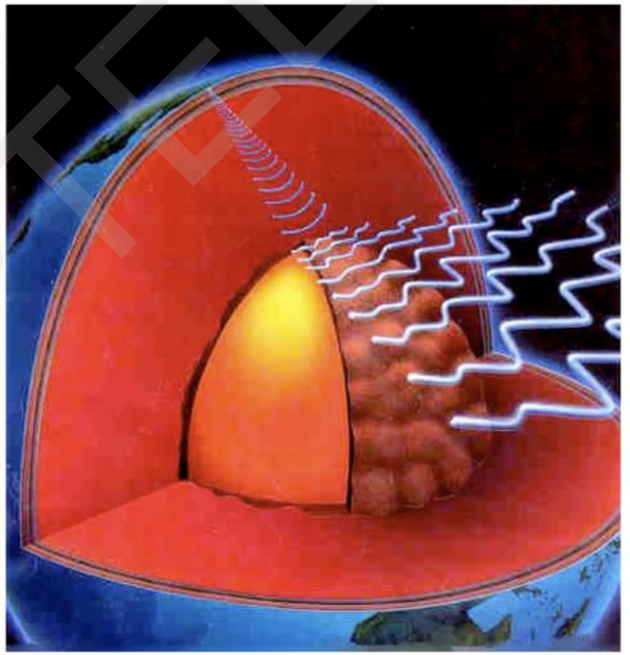


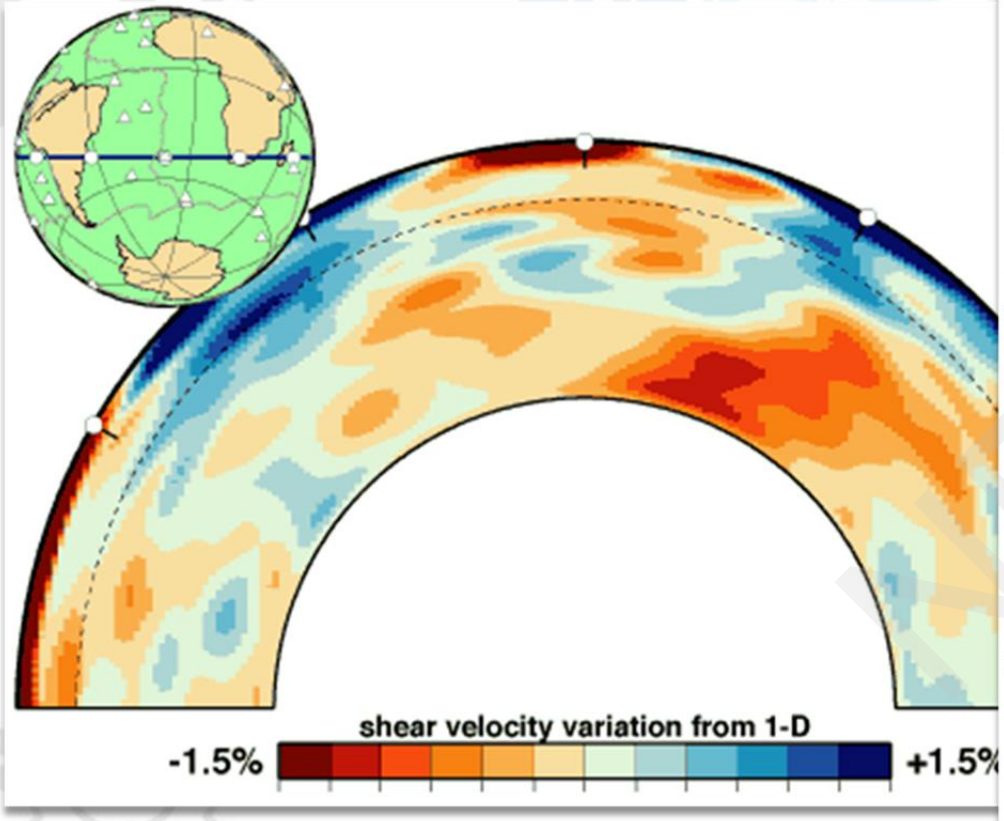
# Ray theory

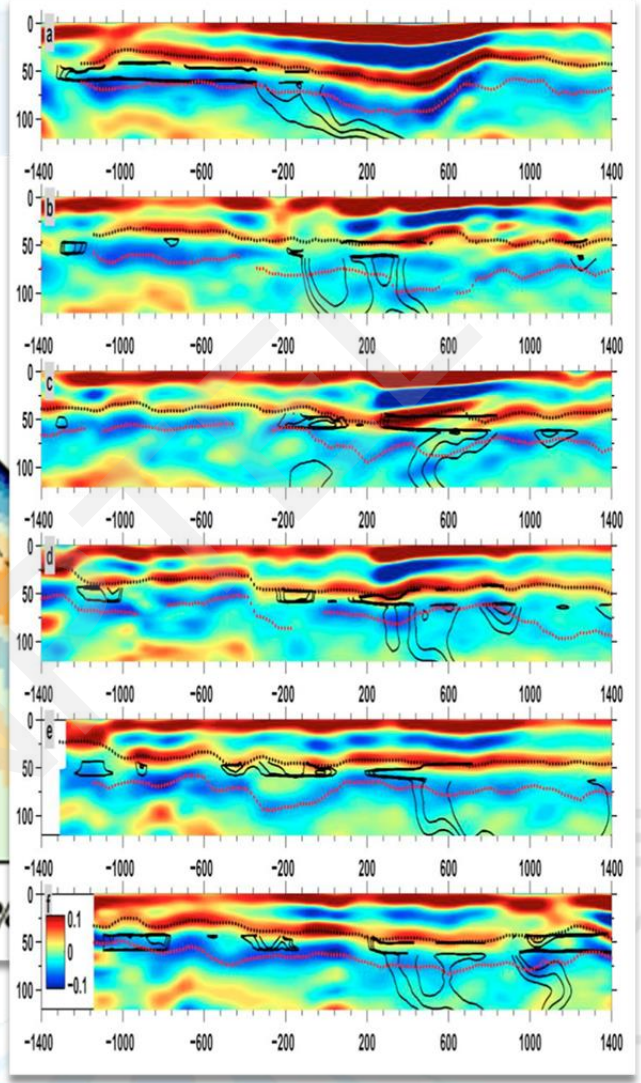
**Geometrical properties (essentially optics) of elastic waves in Earth (Chap. 3 and 7)**

Wave propagation ←→ Earth structure



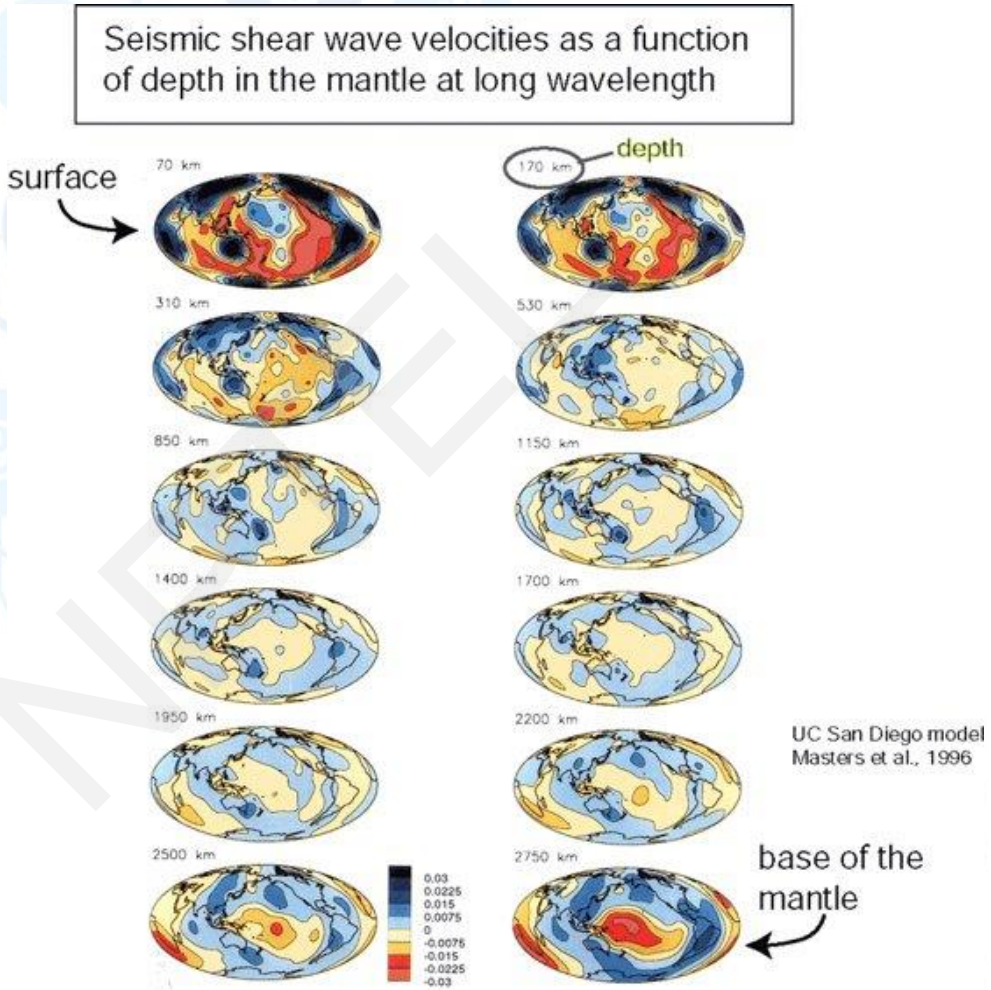



**Nearly everything we know about the deep earth (below 5-15 km) is from seismology.**

# Inversion of data

Seismic "tomography" is an approach of imaging perturbations in a body. Below, we show this for the whole earth. This is also done for much small scales, such as in a fault zone, the crust, a magma chamber, a mid-ocean ridge, etc.



- **More on Ray theory**

**Energy issues – attenuation, transmission / reflection amplitudes, phase**

- **Reflection seismology**

**The study of reflected energy, very important societally (e.g., petroleum resource exploration)**

- **Surface waves:**

**Due to the free surface and the shape of earth. We'll discuss Love waves, Rayleigh waves and normal modes**

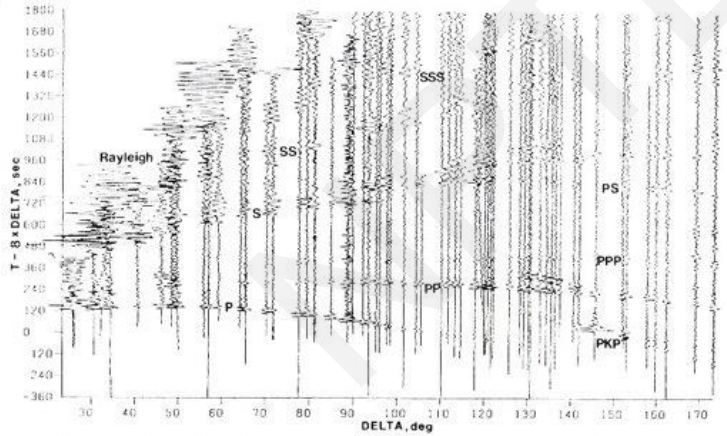



**FIGURE 1.18** A collection of vertical-component seismograms for a single event that occurred near Sumatra, plotted at the angular distance to each station. The records are from the World Wide Standardized and Canadian Seismic Networks. Upward motion on each trace is toward the left. Note that coherent arrivals can be tracked from trace to trace. These define the travel-time behavior for different paths through the Earth. The start time of each trace has been reduced by a value of $8\Delta$ s, where $\Delta$ is the angular distance. Thus, traces on the right begin much later than traces on the left. (Modified from Müller and Kind, 1976. Reprinted with permission of the Royal Astronomical Society.)

# Source theory

## Quantification of the earthquake rupture process

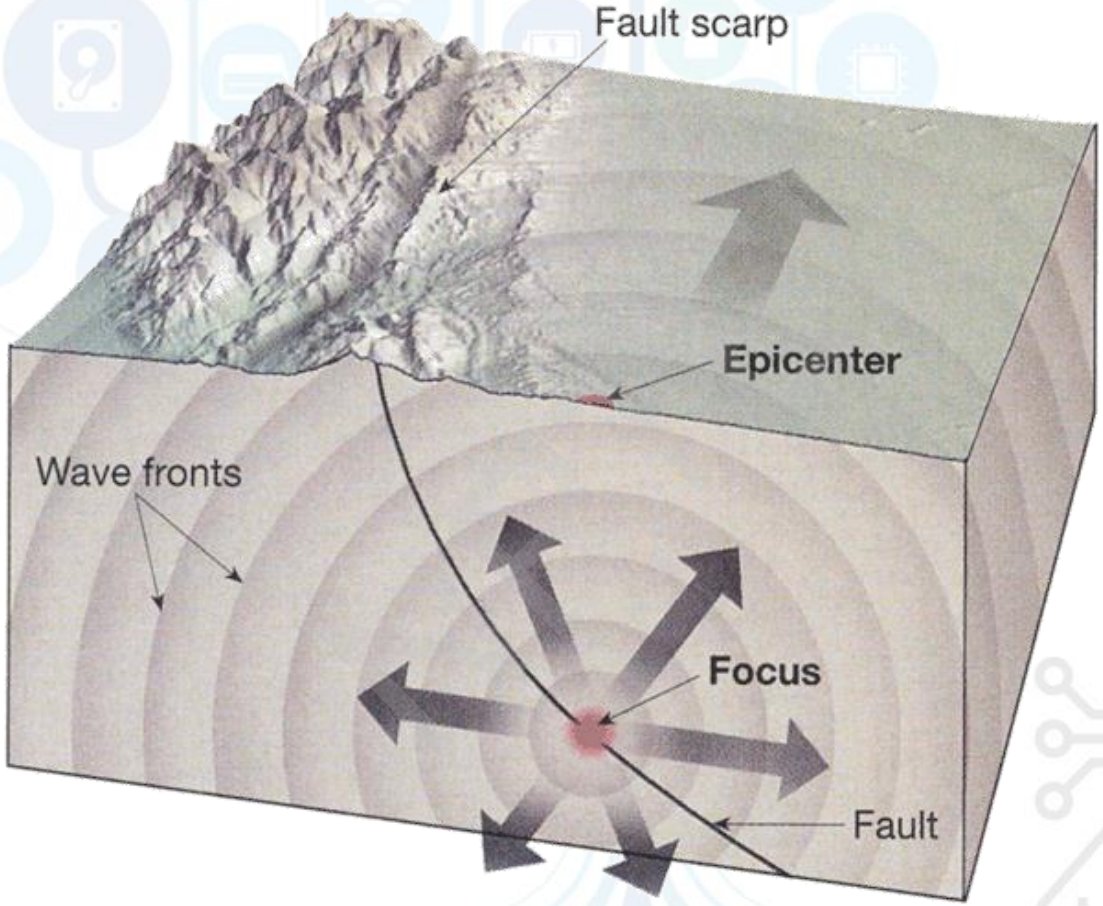
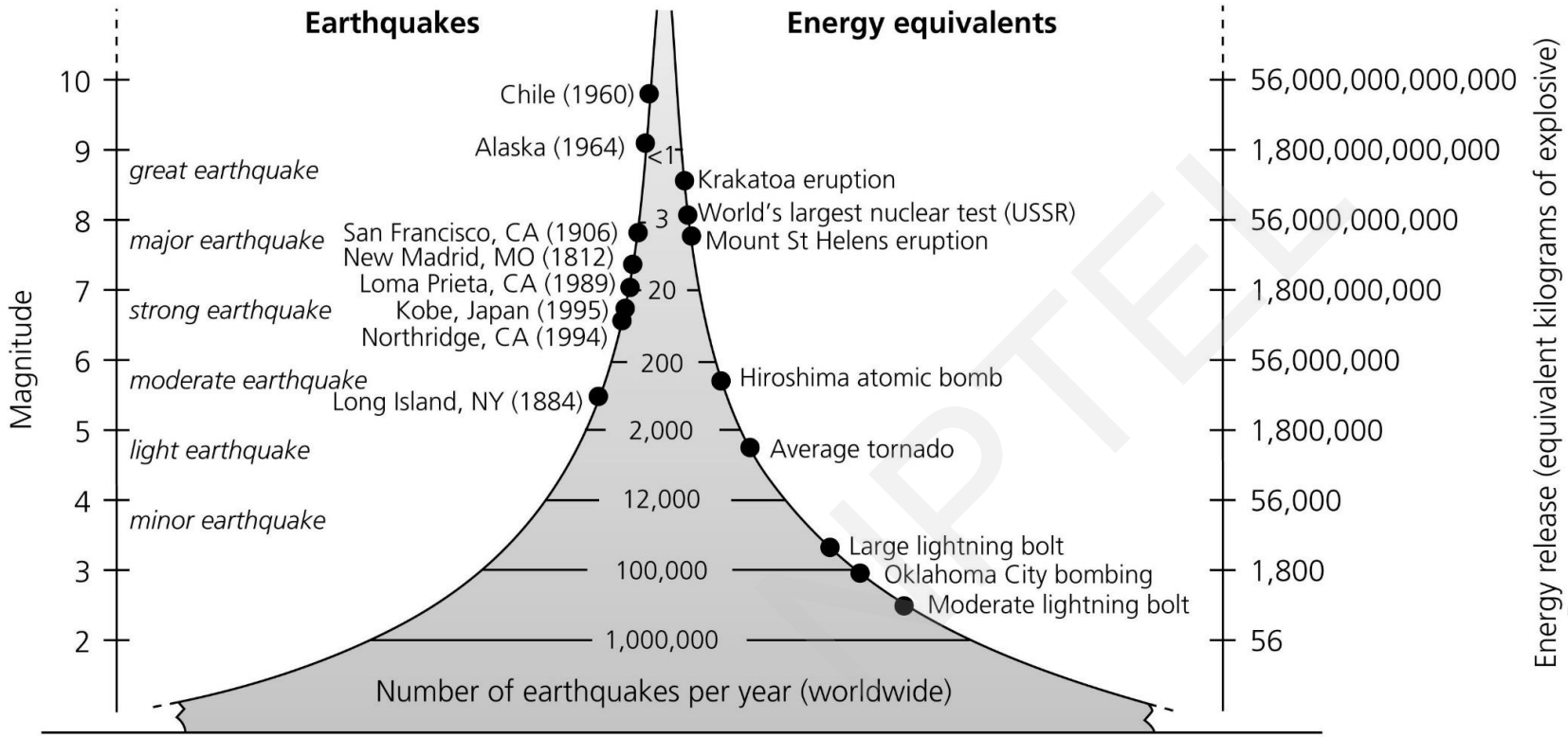


**Figure 1.2-2: Comparison of frequency, magnitude, and energy release.**




(Stein and Wysession)

Comparison of frequency, magnitude, and energy release of earthquakes and other phenomena. The magnitude used is moment magnitude.

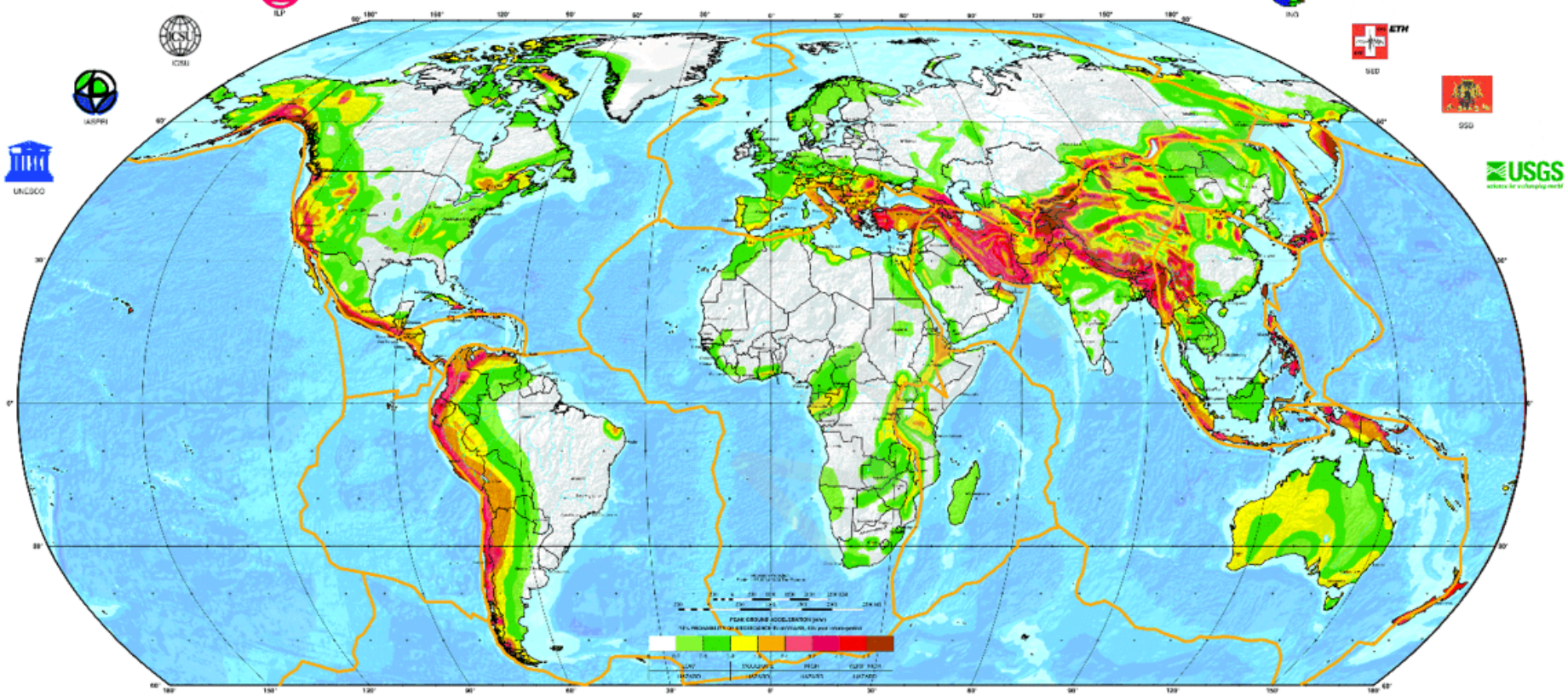
# GLOBAL SEISMIC HAZARD MAP

GFZ POTSDAM

Produced by the Global Seismic Hazard Assessment Program (GSHAP),
a demonstration project of the UN/International Decade of Natural Disaster Reduction, conducted by the International Lithosphere Program.

International Decade for Natural Disaster Reduction
IDNDR
1990 - 2000

Global map assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang
1999



# REFERENCES


- Stein, Seth, and Michael Wysession. An introduction to seismology, earthquakes, and earth structure. John Wiley & Sons, 2009.
- Lowrie, William, and Andreas Fichtner. Fundamentals of geophysics. Cambridge university press, 2020.
- Kearey, Philip, Michael Brooks, and Ian Hill. An introduction to geophysical exploration. Vol. 4. John Wiley & Sons, 2002.
- https://geologyscience.com/geology-branches/structural-geology/stress-and-strain/
- https://www.wikipedia.org/

# THANK YOU !