CE 2141 ENGINEERING GEOLOGY AND GEOMORPHOLOGY

Lecture 05 – Earthquakes and Seismic zones of BD

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Lecture 05: Topics

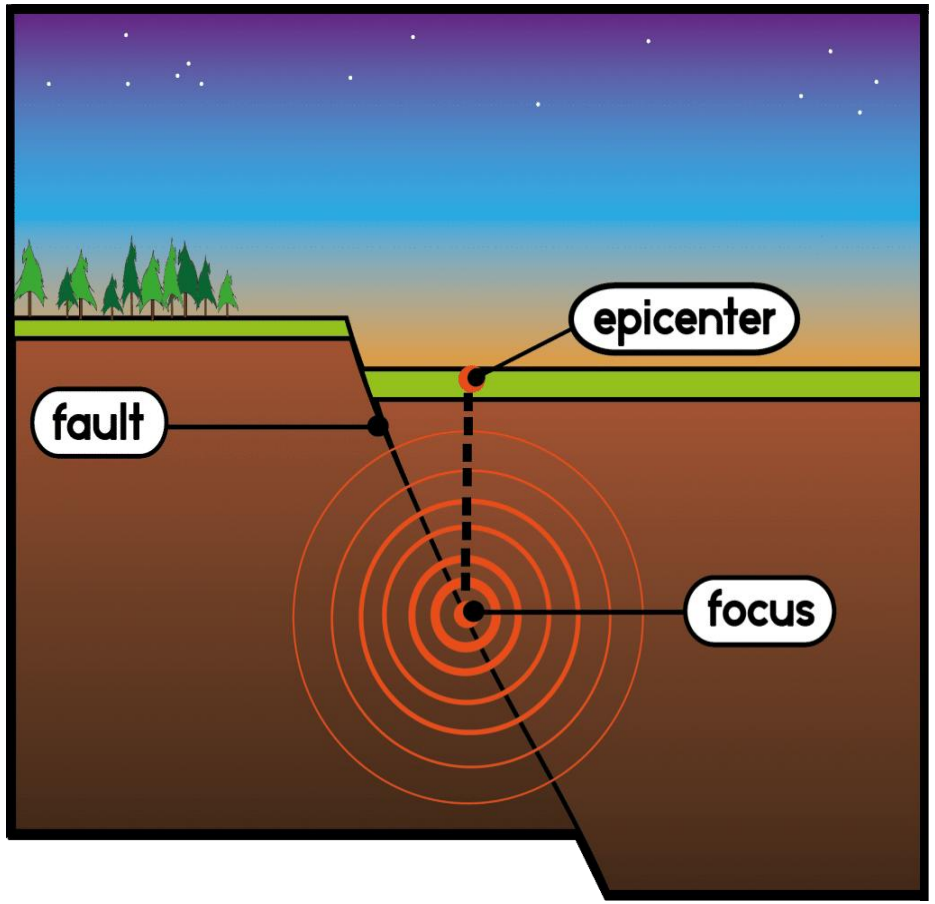
- What is Earthquake and Causes
- Earthquake waves and Their Types
- Measurement of Earthquake/Seismic Forces
- Intensity and Magnitude of Earthquake
- History of Major Earthquake Disasters and their Effects
- Seismic Zones of Bangladesh

What is Earthquake

- The natural vibration of the ground (or the Earth's crust) produced by forces, called **Earthquake** forces or **Seismic** forces.
- Some times these vibrations are very feeble, not even felt by human.
- But some vibrations are **severe and cause rupture of building and structures**.

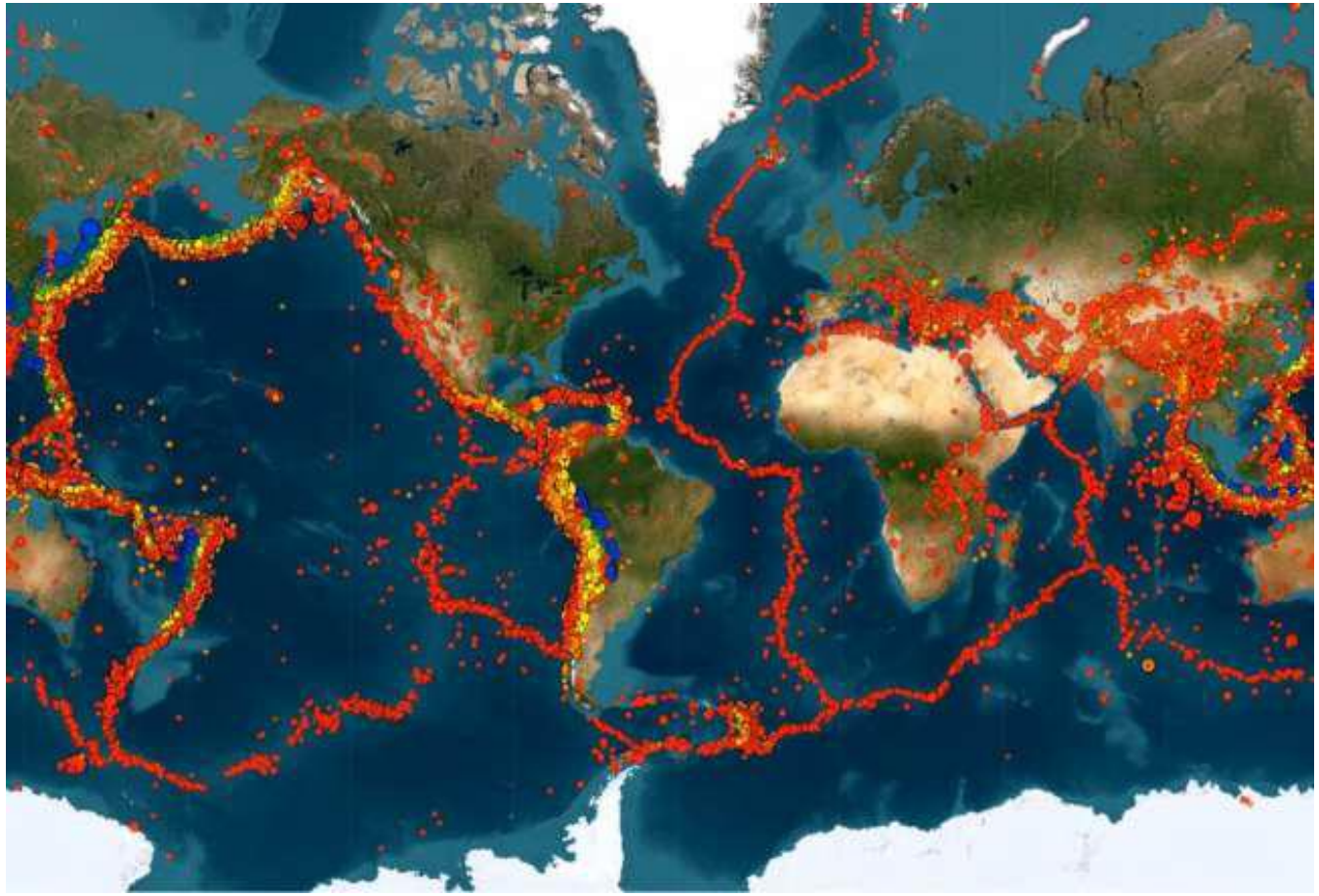
Focus & Epicenter

- An earthquake originates at a point within the Earth called the **Focus**. This is the point where the seismic energy is first released due to the movement of tectonic plates along a fault line.
- The point on the Earth's surface directly above the focus is called the **Epicenter**, where the earthquake waves reach first.



Where do Earthquakes Occur

- About 80% of earthquakes occur along tectonic plate boundaries.
- Some also occur within plates due to stress buildup and fault lines, though these are less frequent.



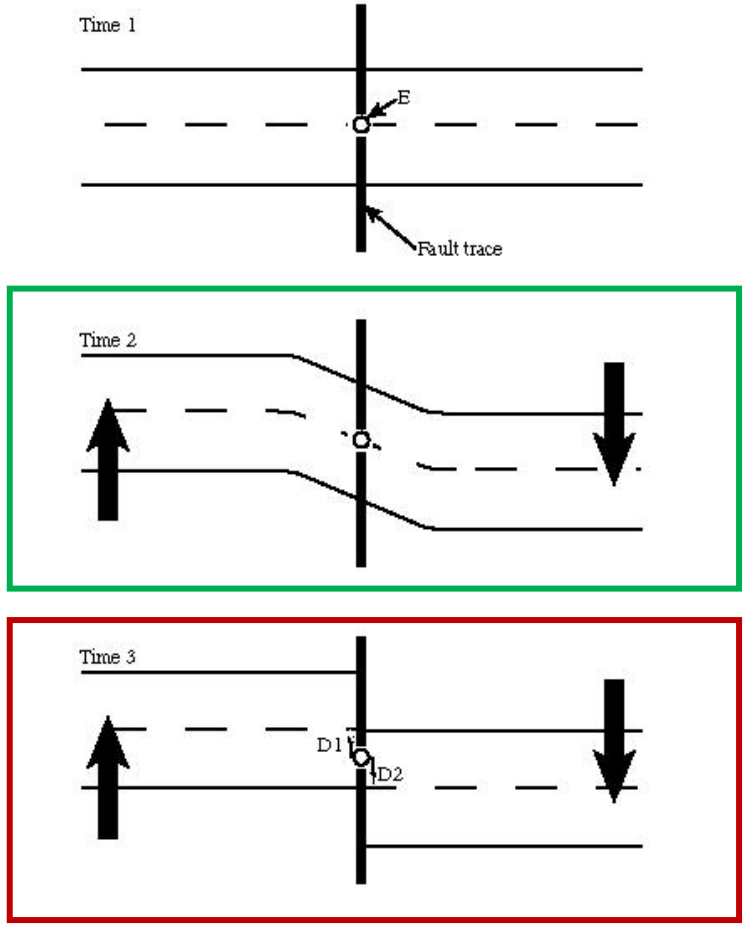
What causes Earthquake

Depending on the possible cause earthquakes can be classified as following 2 categories -

- **Tectonic Earthquake,** caused by slippage or movement of rock masses along a rupture or break called **Fault.**
- **Non-tectonic Earthquake,** can be caused by volcanic eruptions, landslides, subsidence of ground below the surface.

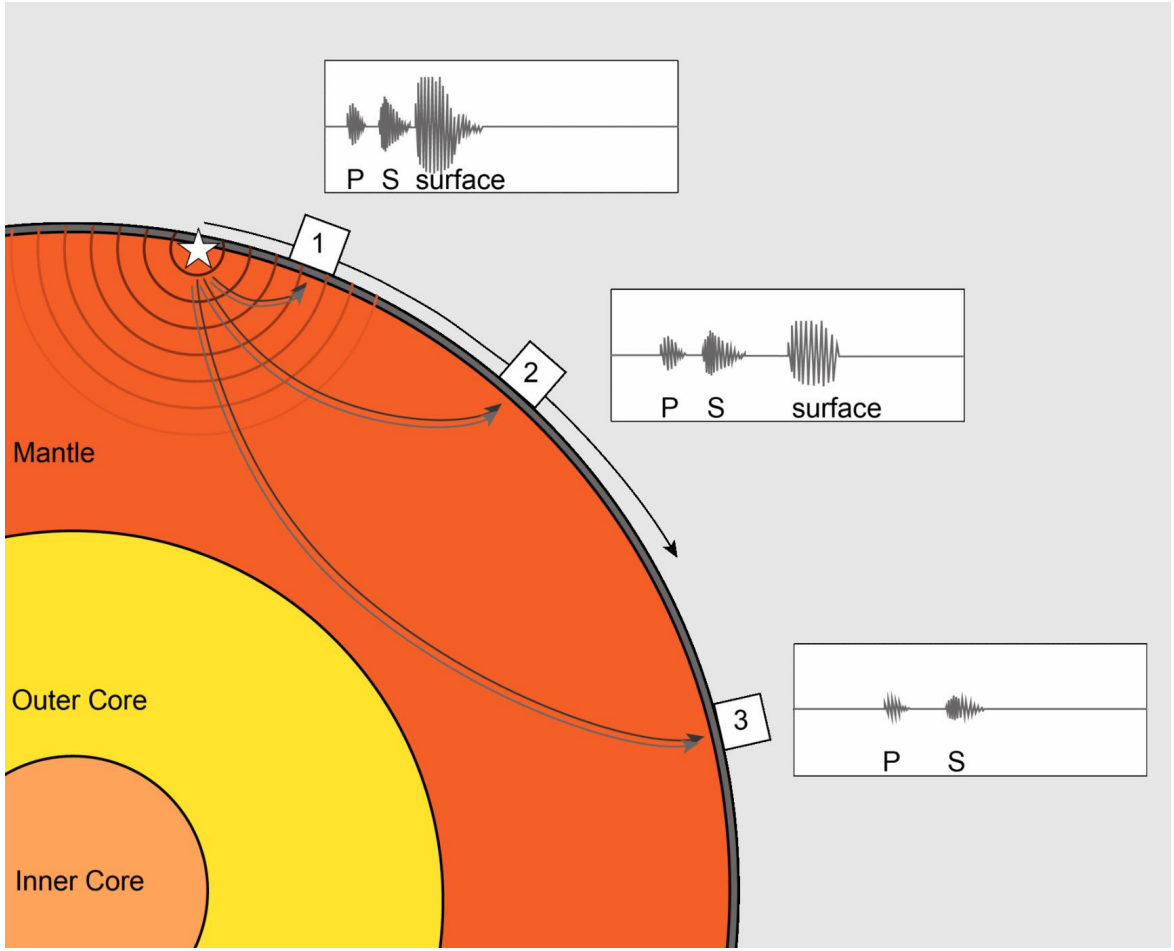
The Elastic Rebound Theory

- Most natural earthquakes are caused by sudden slippage along a fault zone.
- The elastic rebound theory suggests that if slippage along a fault is hindered such that **elastic strain energy** builds up in the **deforming rocks** on either side of the fault, when the **slippage** does occur, the **energy released** causes an earthquake.



Earthquake Waves

When an earthquake occurs, the elastic energy is released sending out vibrations that travel throughout the Earth. These vibrations are called **Earthquake Waves** or **Seismic Waves.**

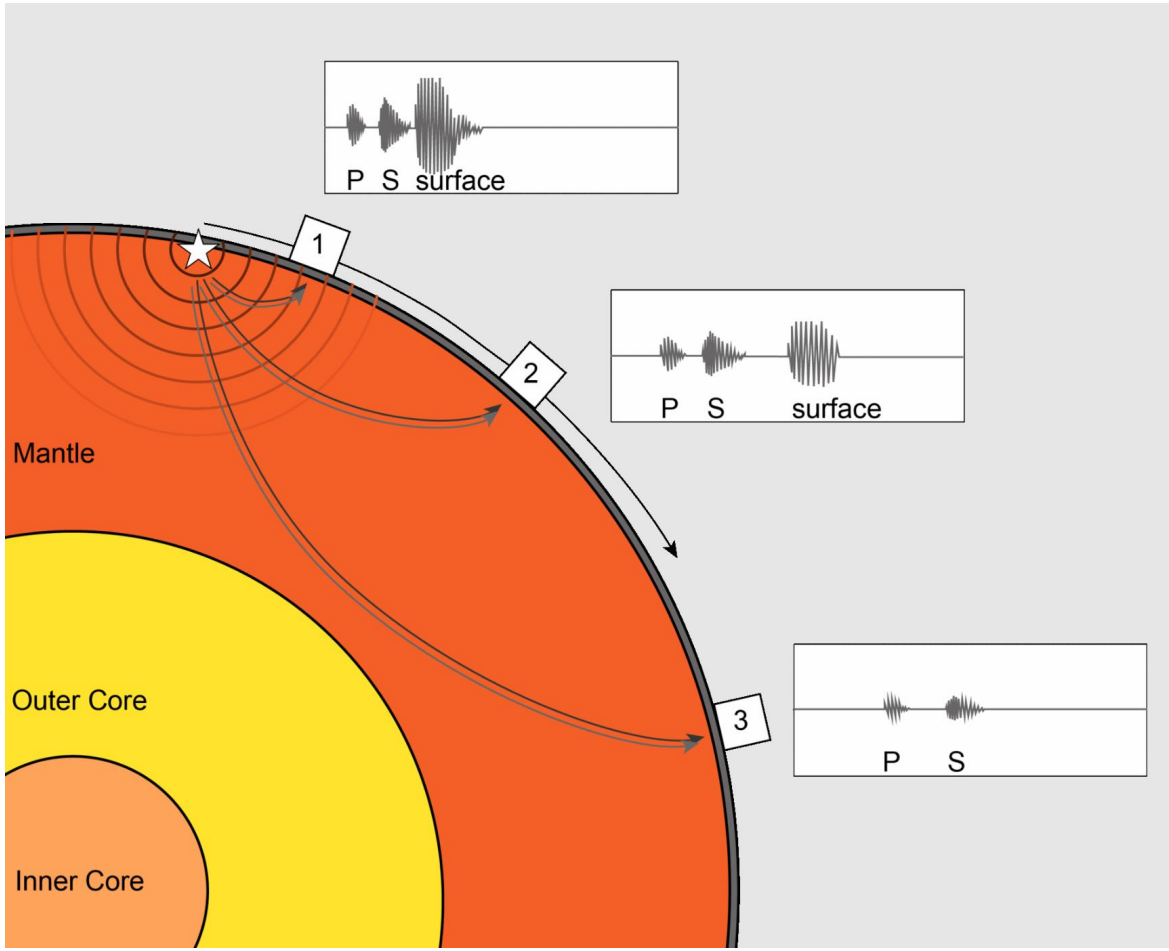


Types of Earthquake Waves

Earthquake Waves or **Seismic Waves** are divided into 2 major category,

1) Body Wave moves through the interior of the Earth.

2) Surface Wave travels along the surface of the Earth. This type wave is responsible for the damage.



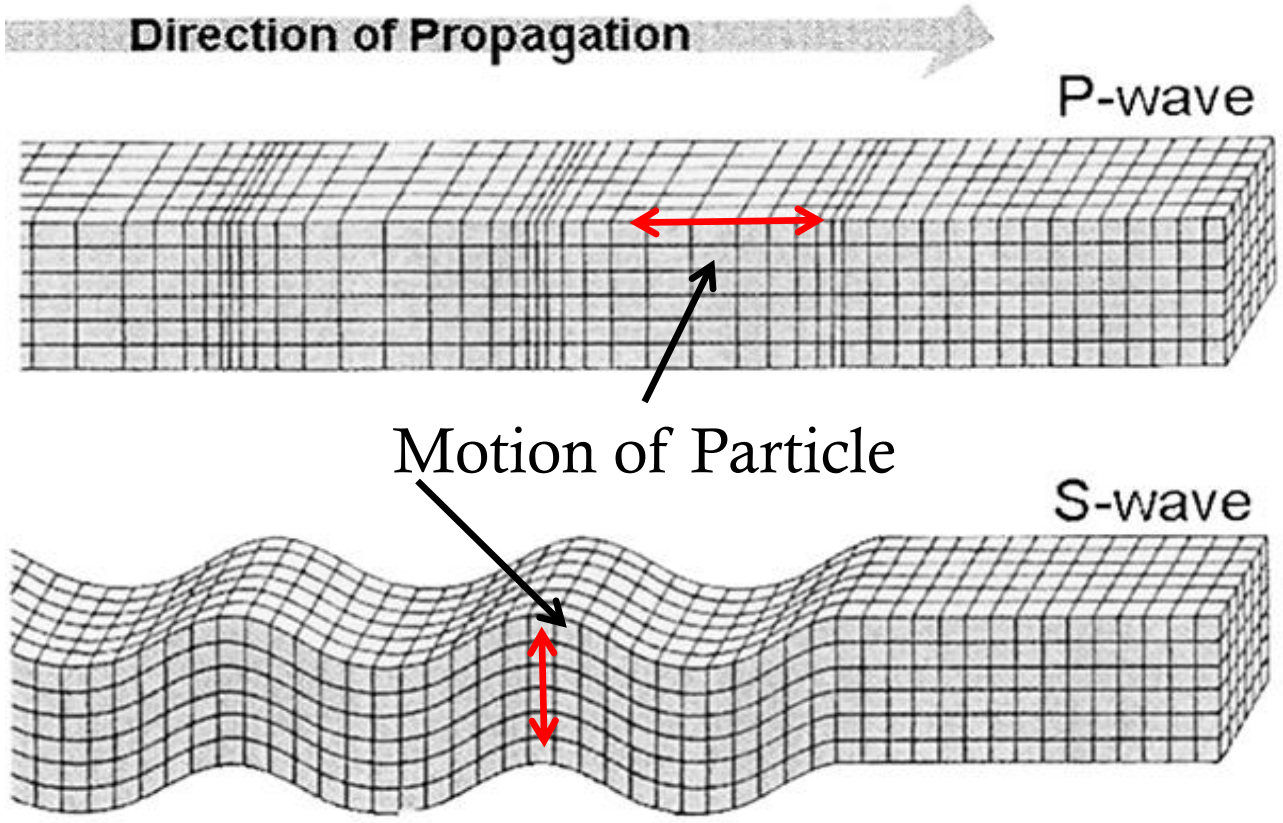
Types of Body Waves

1) Primary or P-Wave

P waves cause the ground to compress and expand, that is, to move back and forth, in the direction of travel.

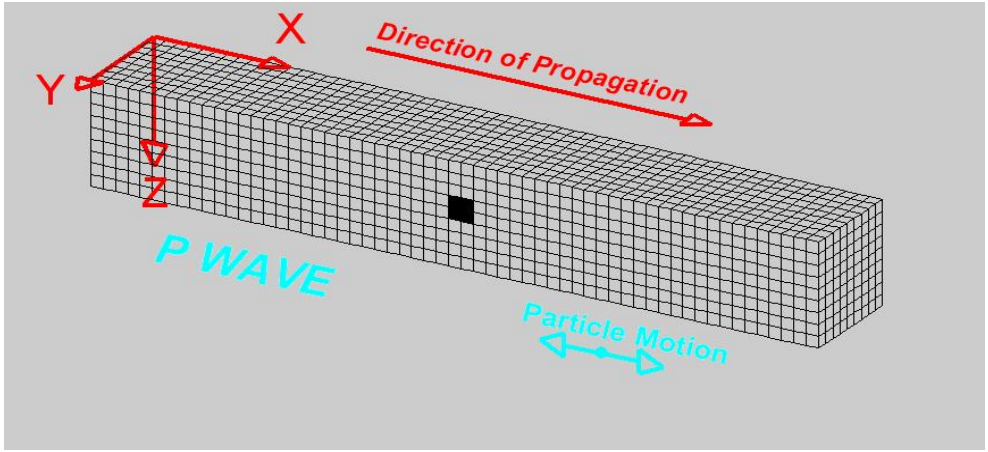
2) Secondary or S-Wave

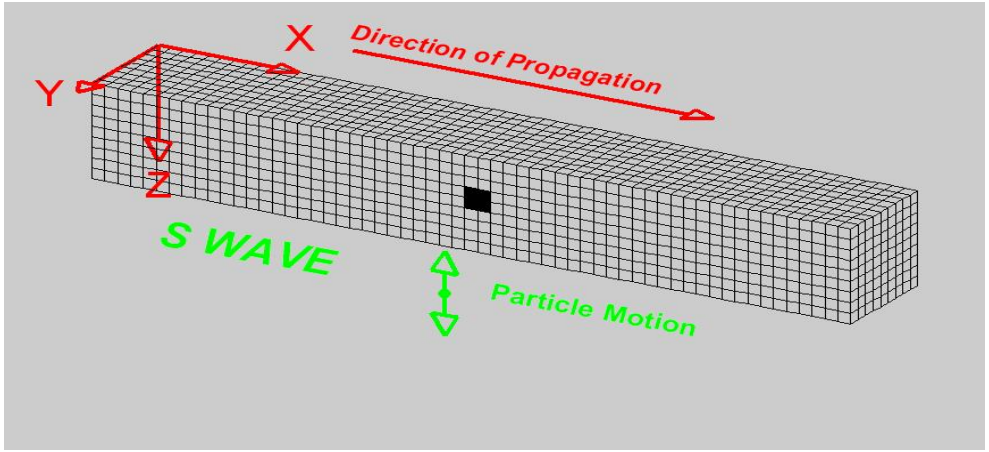
S waves shake the ground in a shearing, or crosswise, motion that is perpendicular to the direction of travel.



P-Wave vs S-Wave

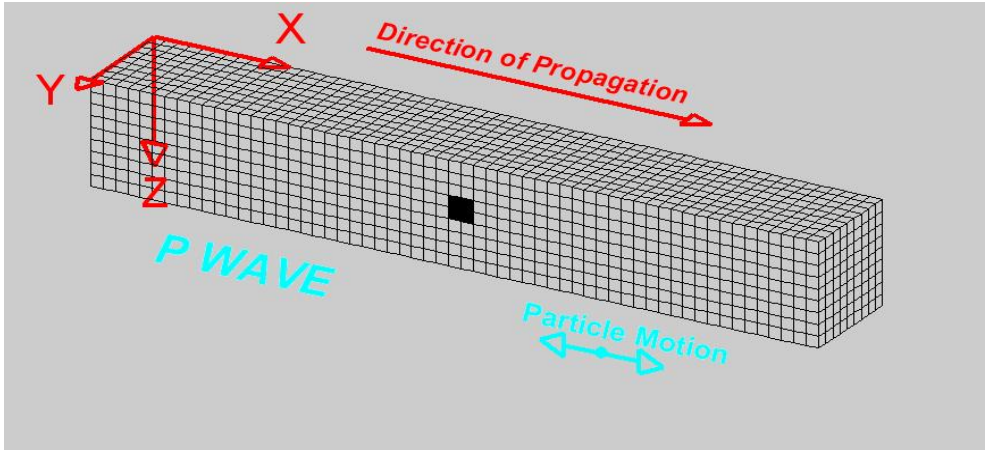
Longitudinal waves.	Transverse waves.
Pass trough both solids and liquids.	Can not move through liquids.
Move forwards and backwards as it compressed and decompressed.	Move in all direction from their source.

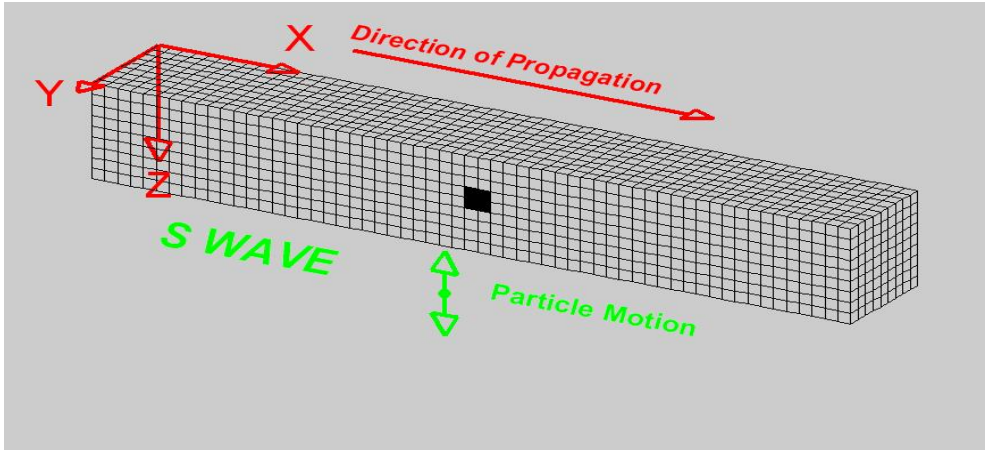




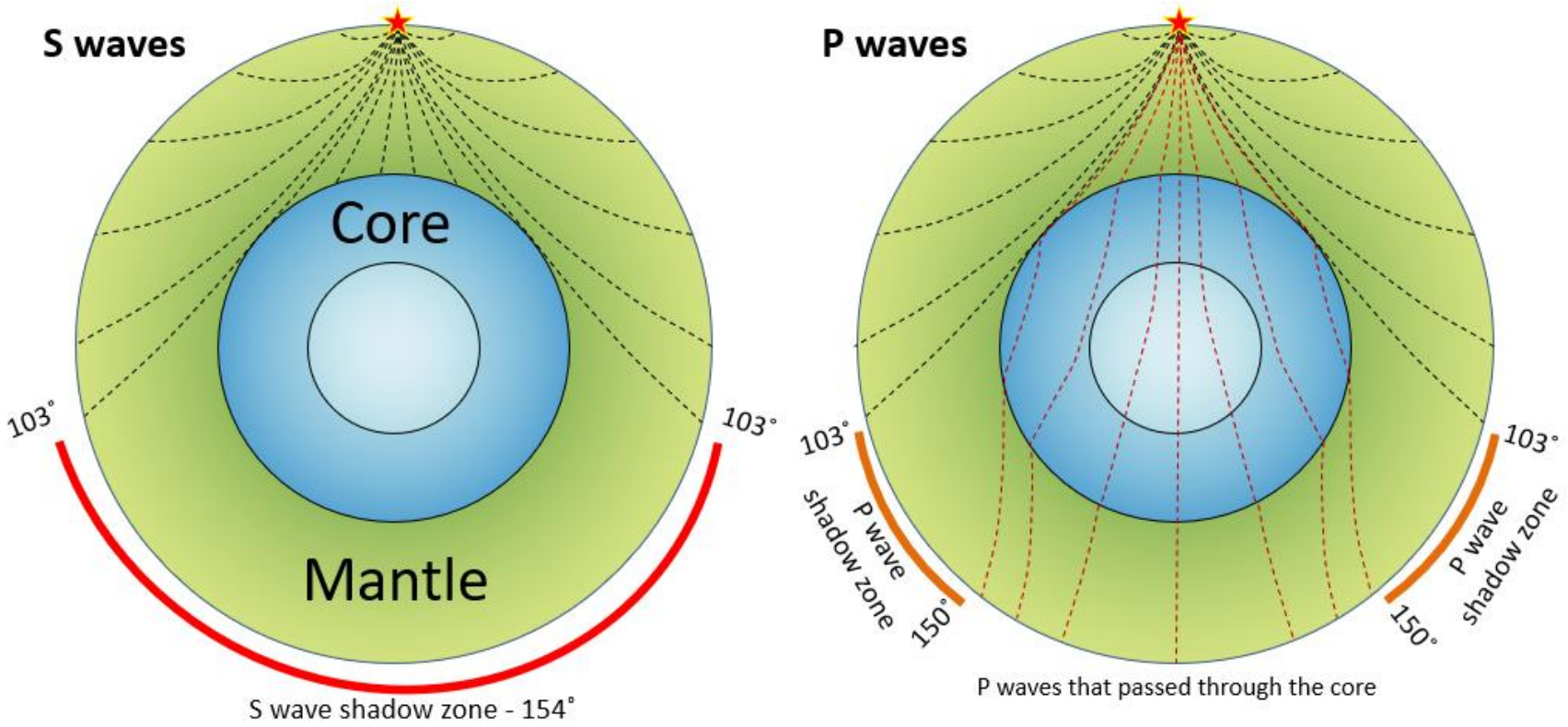
P-Wave vs S-Wave

P-wave is faster.	S-wave is slower than P-wave.
First P-wave arrive in the surface.	After P-wave S-wave arrives.





Understanding Earth's Internal Structure will Seismology



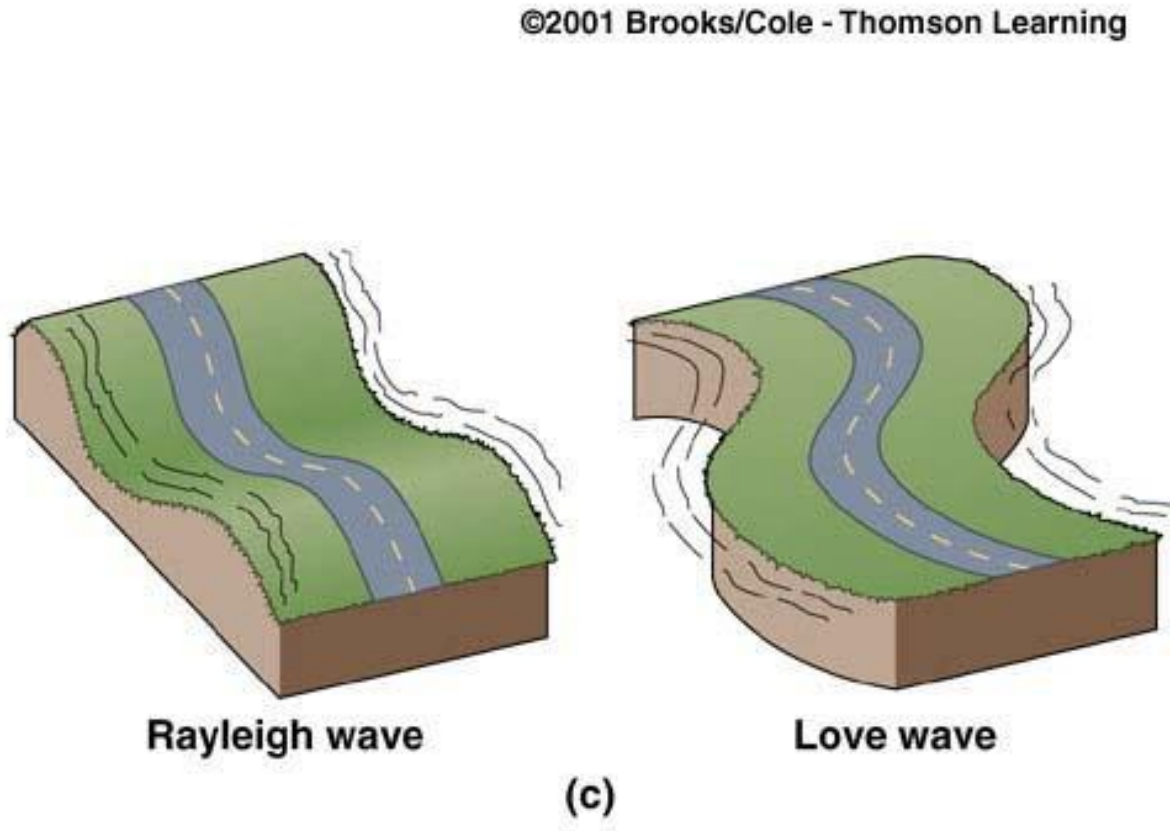
Types of Surface Waves

1) Rayleigh or R-Waves

Characterized by a rolling, elliptical motion of the ground surface.

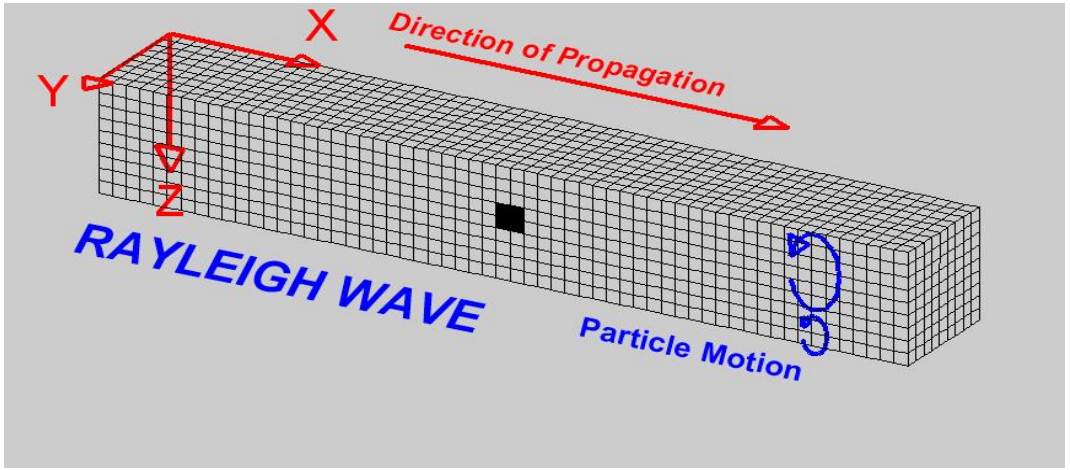
2) Love or L-Waves

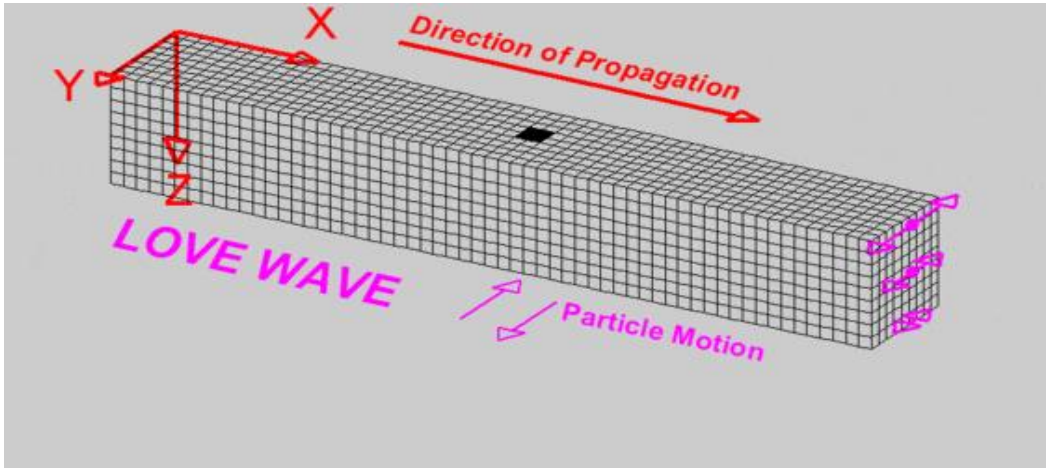
Characterized by a horizontal side-to-side motion of the ground.



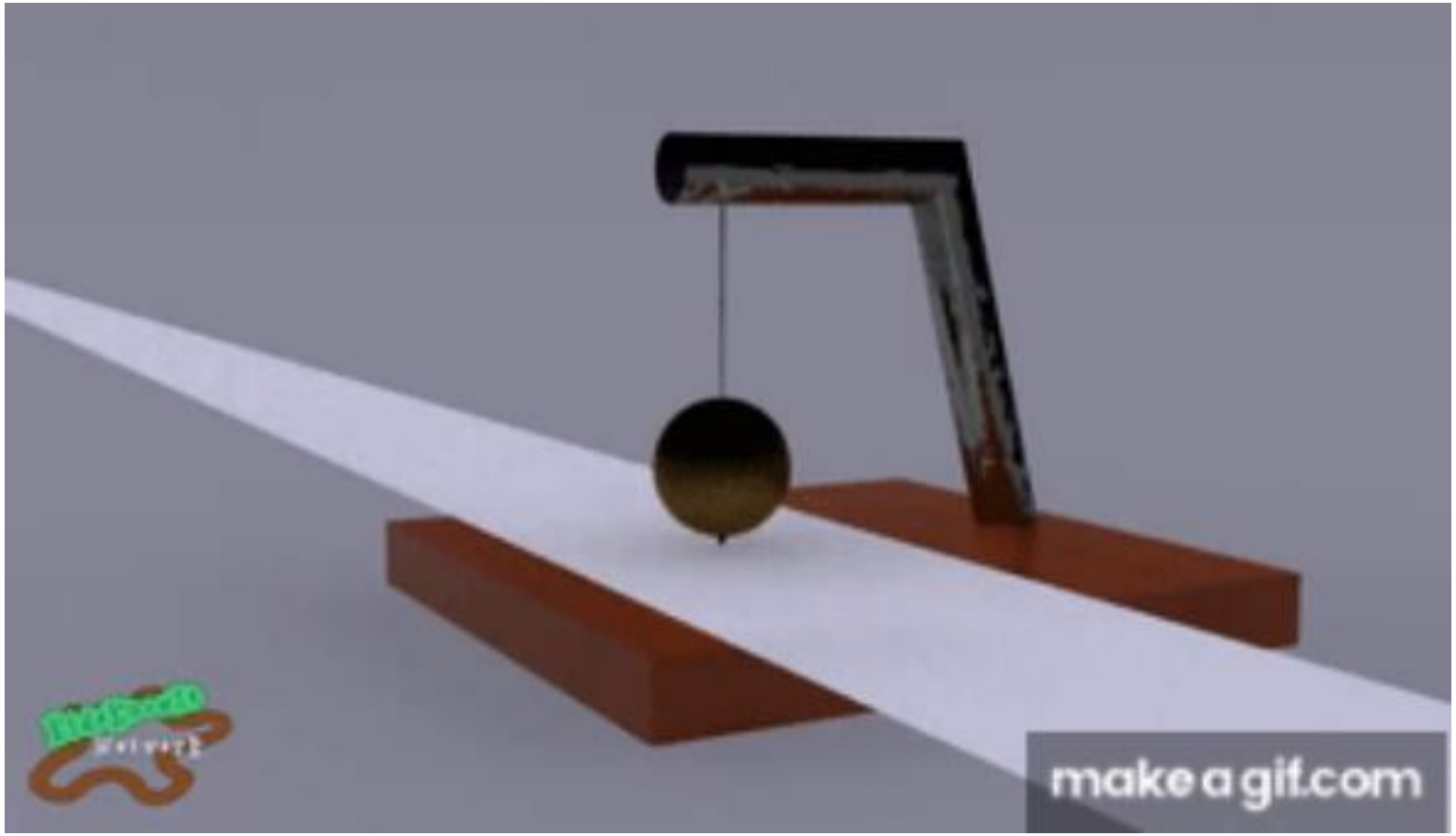
R-Waves vs L-Wave

Particles move both vertically and horizontally in the direction of wave propagation.	Particles move perpendicular to the direction of wave propagation.
They are slower than L-waves and body waves.	Travel faster than Rayleigh waves.
They cause the most noticeable shaking during an earthquake but less destructive than L-wave.	Love waves are known for causing the most damage during an earthquake.



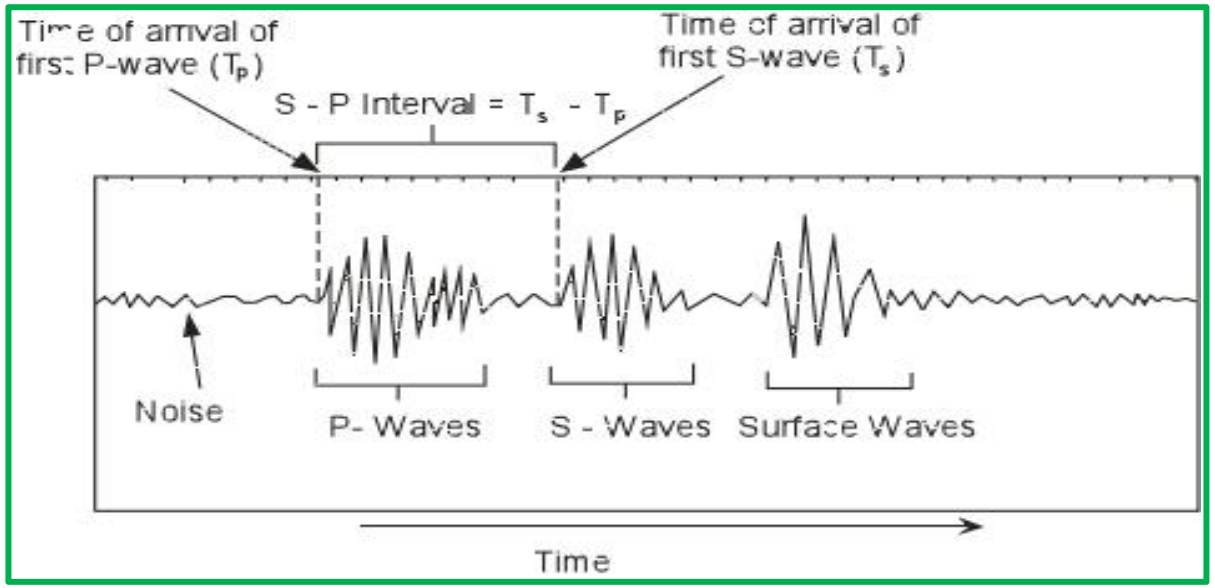


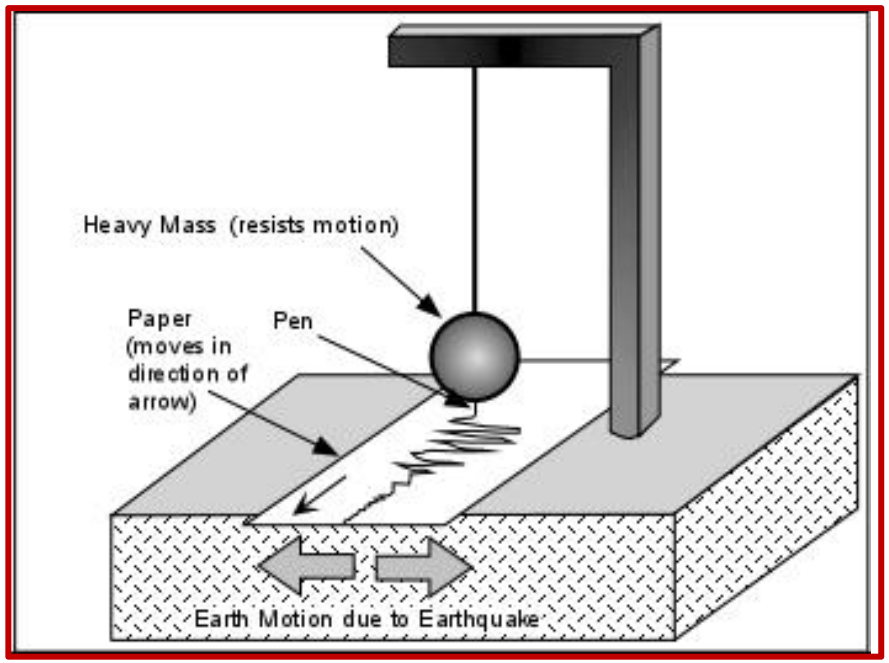
Measurement of Earthquake or Seismic Force



Measurement of Earthquake or Seismic Force

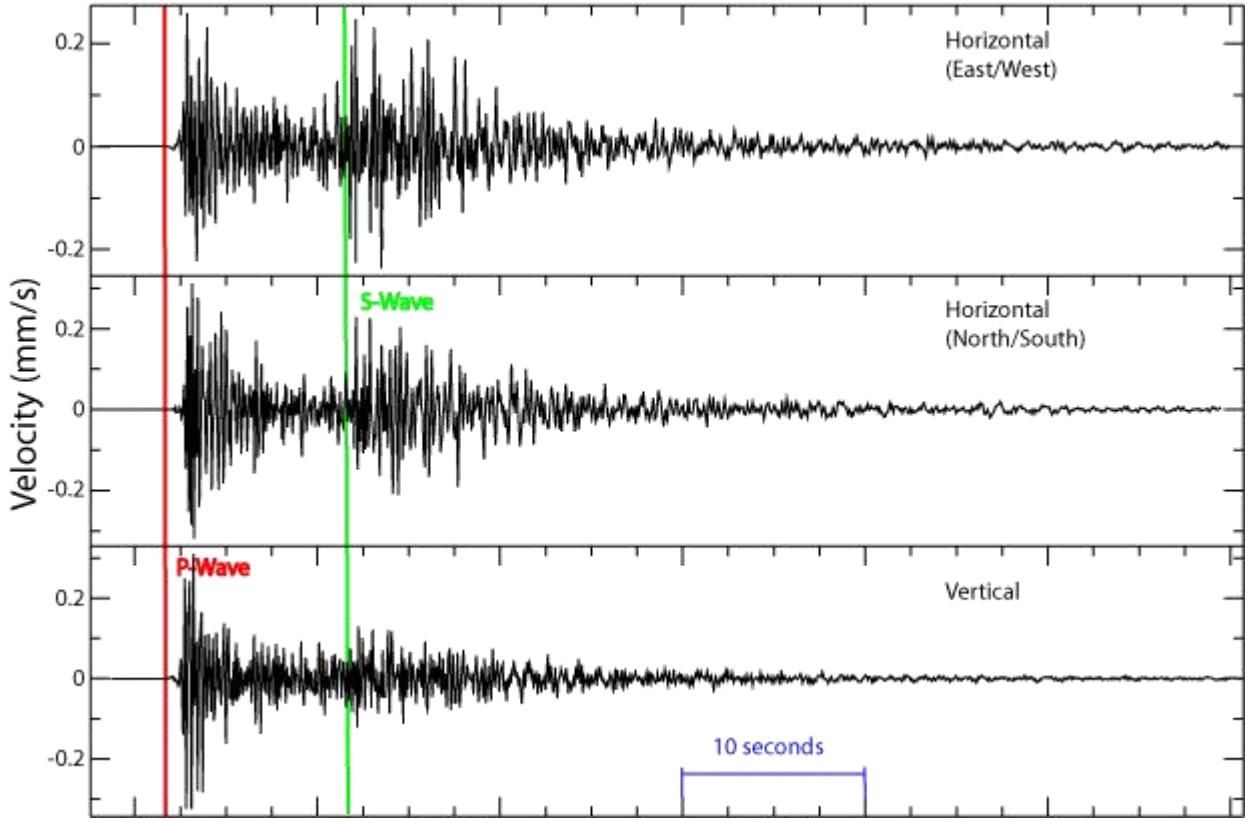
Seismic waves travel through the Earth as vibrations. A **Seismometer** is an instrument used to record these vibrations, and the resulting graph that shows the vibrations is called a **Seismogram**.





Measurement of Earthquake or Seismic Force

To record ground vibrations in all three spatial directions, you need three Seismometers. Each seismometer is designed to measure motion along a single axis (e.g., north-south, east-west, and vertical)



Locating Epicenter using Triangulation Method

Calculating Distance:

By measuring the time difference between the arrival of P-waves and S-waves we can determine the distance of Epicenter using Travel Time Curve.

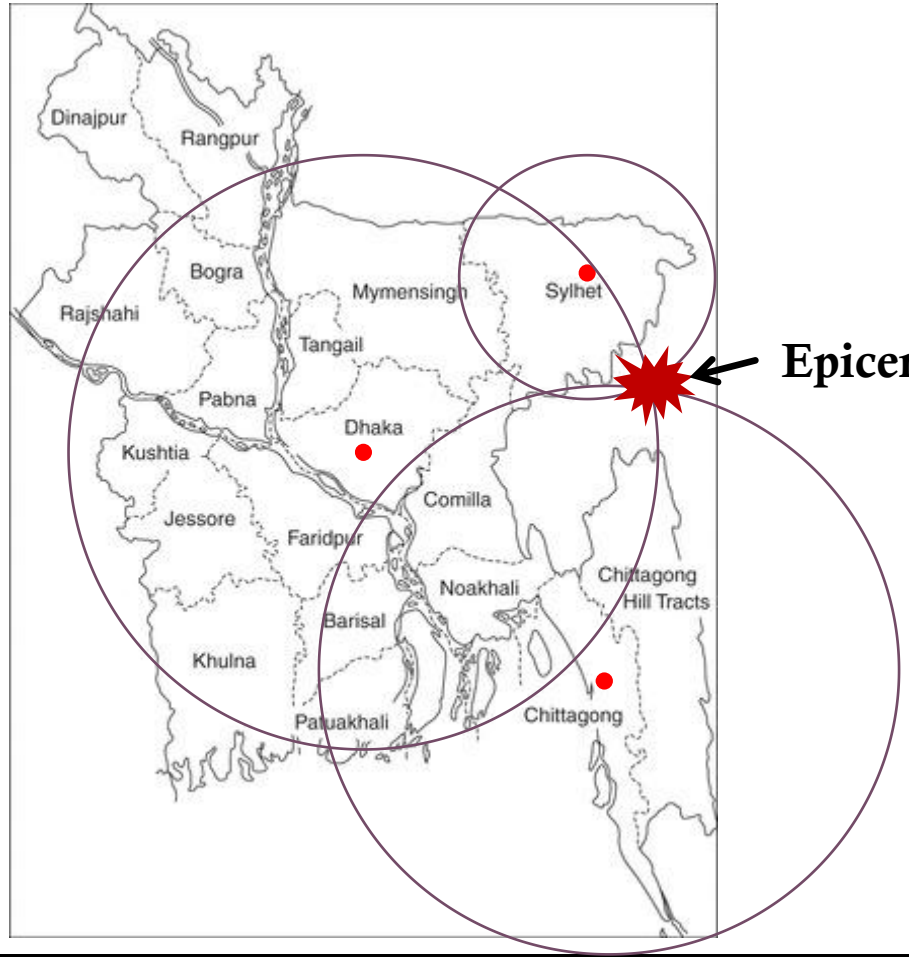
Triangulation:

Using the calculated distances, circles are drawn on a map around each seismic station, with the radius of each circle representing the distance to the epicenter.

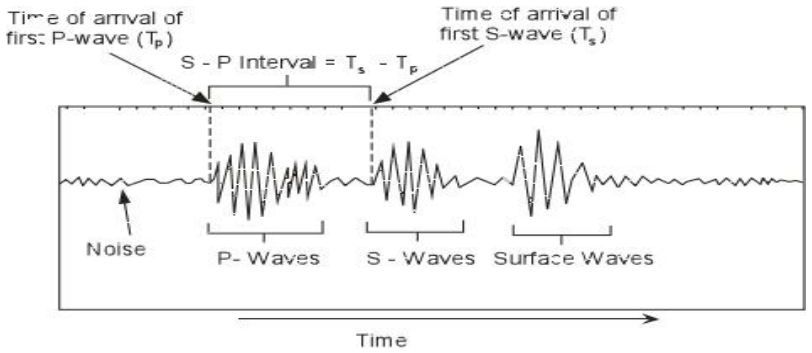
Epicenter Location:

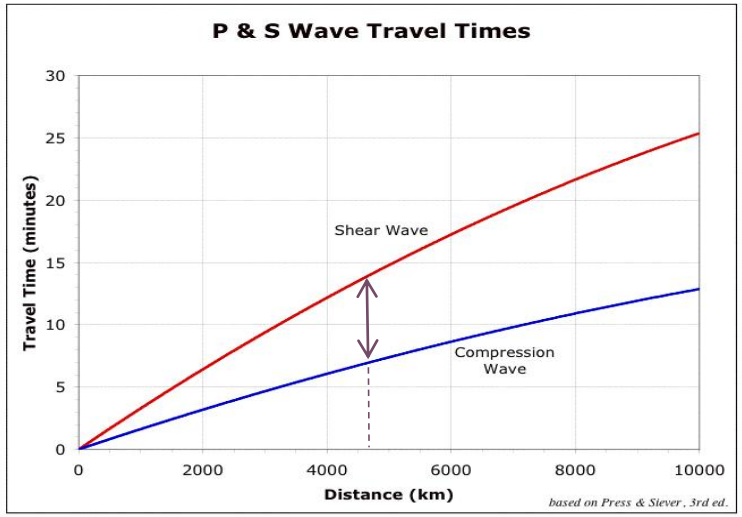
The point where the circles intersect (or nearly intersect) represents the earthquake's epicenter. At least 3 locations are needed for this method.

Locating Epicenter using Triangulation Method



Epicenter





Intensity of an Earthquake

- It can be defined as the rating of an earthquake based on the actual effects produced by the quake on the Earth.
- These observed effects range from simple harmless vibrations to strong jerks capable of collapse of buildings.

Modified Mercalli's Intensity Scale

I. Instrumental	Not felt by many people unless in favourable conditions.
II. Feeble	Felt only by a few people at best, especially on the upper floors of buildings. Delicately suspended objects may swing.
III. Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV. Moderate	Felt indoors by many people, outdoors by few people during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. Dishes and windows rattle alarmingly.
V. Rather Strong	
VI. Strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
VII. Very Strong	Difficult to stand; furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars.

Intensity of an Earthquake

- It can be defined as the rating of an earthquake based on the actual effects produced by the quake on the Earth.
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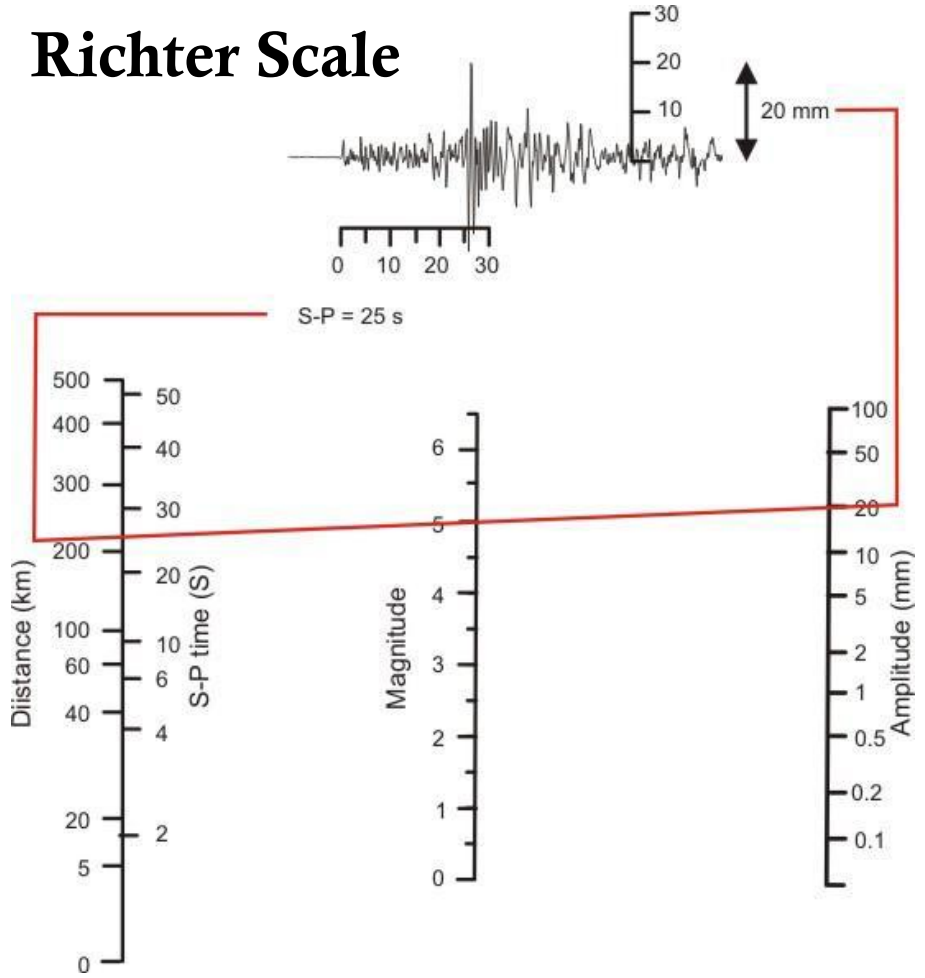
Modified Mercalli's Intensity Scale

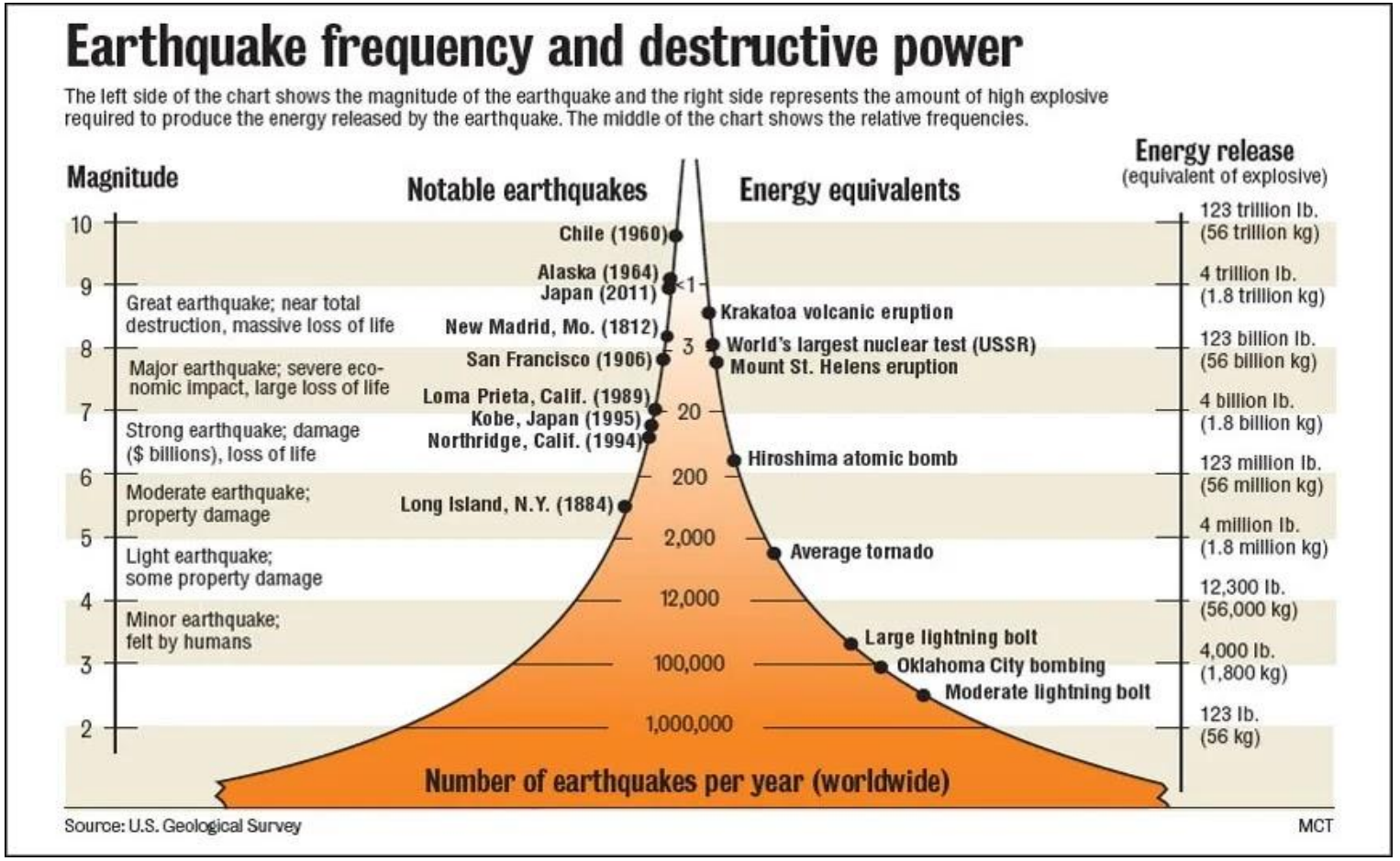
VII. Very Strong	Difficult to stand; furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars.
VIII. Destructive	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
IX. Ruinous	General panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Disastrous	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent.
XI. Very Disastrous	Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Catastrophic	Total damage - Almost everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move position.

Magnitude of an Earthquake

- Magnitude is the size of an earthquake based on the total amount of energy released by it.
- Richter scale is used to classify the magnitude of earthquakes.
- The higher Richter value indicates the earthquake released higher energy.



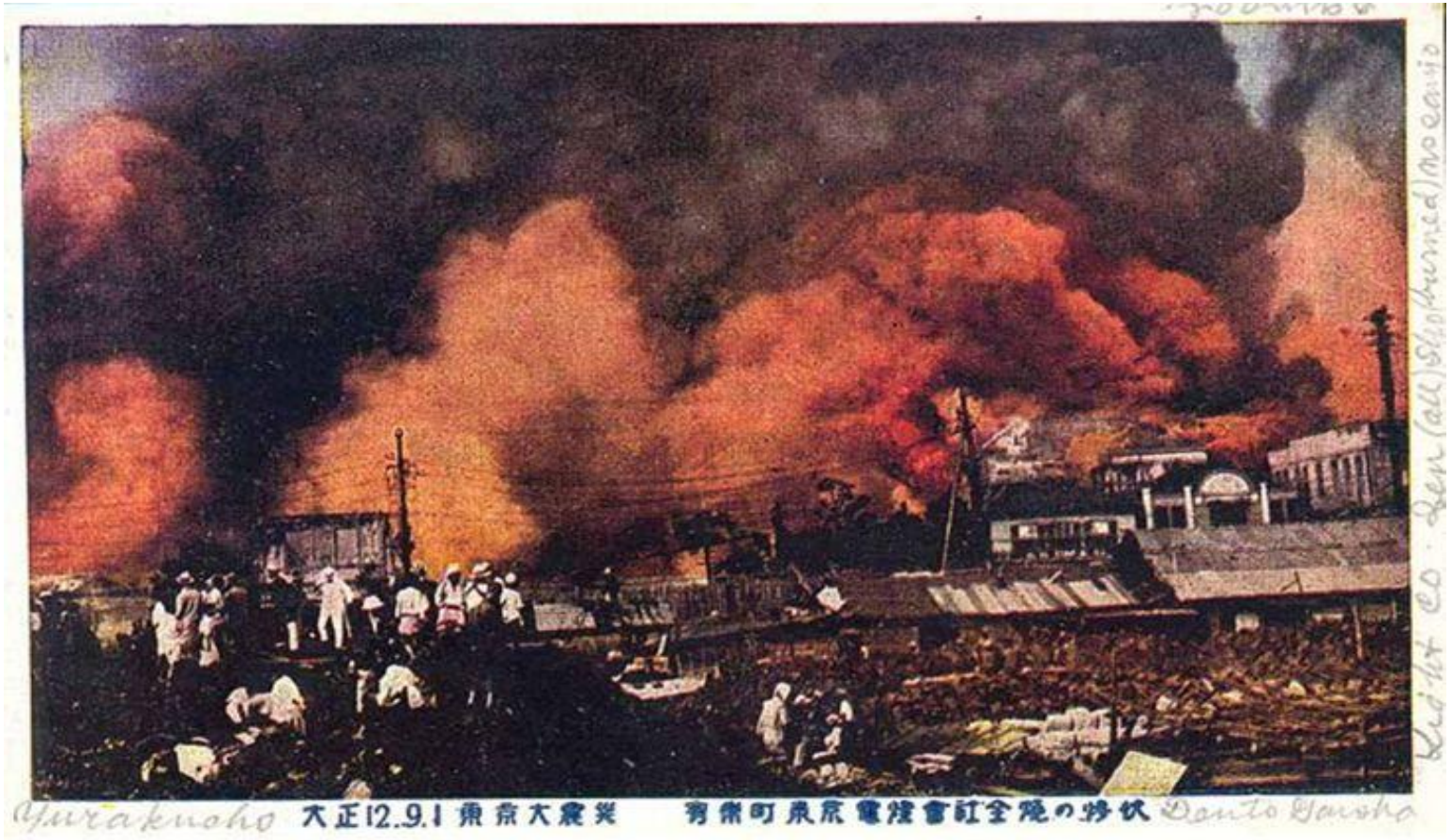
Magnitude of Notable Earthquakes



Effects of Major Earthquakes

Tsunami
Japan 2011

Effects of Major Earthquakes



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Fire
Japan 1923

Effects of Major Earthquakes

Landslide
Nepal 2015

Effects of Major Earthquakes

Ground Displacement Nepal 2015

Effects of Major Earthquakes

Ground Cracks
Chile 2020

Effects of Major Earthquakes

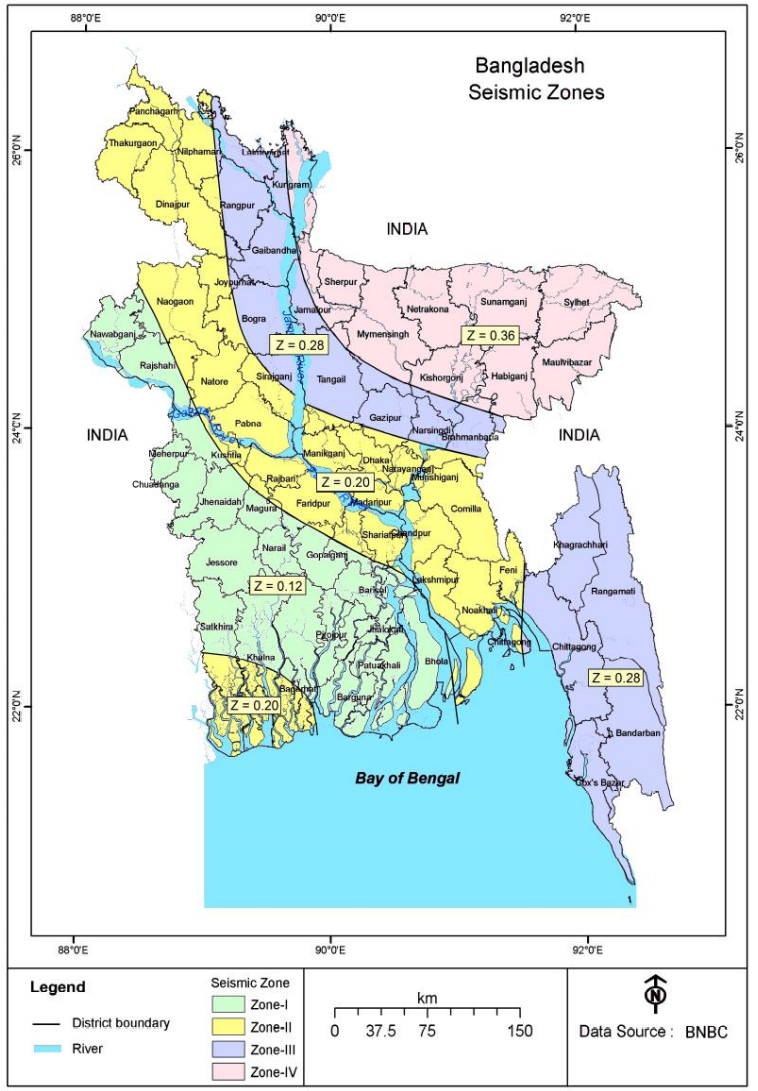
Dam Failure and Flood
Taiwan 1991

Seismic Zones of Bangladesh

The country has been divided into four seismic zones with different levels of ground motion. Each zone has a seismic zone coefficient (Z) which represents the maximum considered peak ground acceleration (PGA) on very stiff soil/rock (site class SA) in units of g (acceleration due to gravity).

The zone coefficients (Z) of the four zones are: Z = 0.12 (Zone 1), Z = 0.20 (Zone 2), Z = 0.28 (Zone 3) and Z = 0.36 (Zone 4).

The zone 4 is more prone to earthquake as, the Dauki Fault locates there.



Seismic Forces in Design Consideration

Design Seismic Base Shear, V_B

From IS 1893- 2002, Clause 7.5.3, the design base shear

$$V_B = A_h W$$

where,

W - seismic weight of the building

A_h - horizontal seismic coefficient

Horizontal Seismic Coefficient, A_h

As per IS 1893(Part 1)-2002, Clause 6.4.2

$$A_h = \frac{Z I S_a}{2 R g}$$

Provided that for any structure with T < 0.1 s, the value of A_h will not be taken less than Z/2 whatever be the value of I/R.