

Lecture # 3

◦ IN THE NAME OF ALLAH,
THE MOST BENEFICENT
AND MOST MERCIFUL.

What is Seismology???

- Seismology is the science that studies seismic waves and what they tell us about the structure of Earth and physics of Earthquake.
- Detail Study of seismic waves is also known as Seismology.

What are Earthquakes.....????????

- Earthquake is a natural phenomenon caused by the geological/tectonic actions in the faulted or ruptured rock. Large amount of energy is released in the form of elastic waves and cause disruption at the earth.

Seismic Waves

- **Seismic waves** are the waves of energy caused by the sudden breaking of rock within the earth.
- The energy released is in the form of waves by an earthquake.

TYPES OF SEISMIC WAVES

- There are two types of seismic wave, namely,
 - 1) Body waves
 - 2) Surface waves
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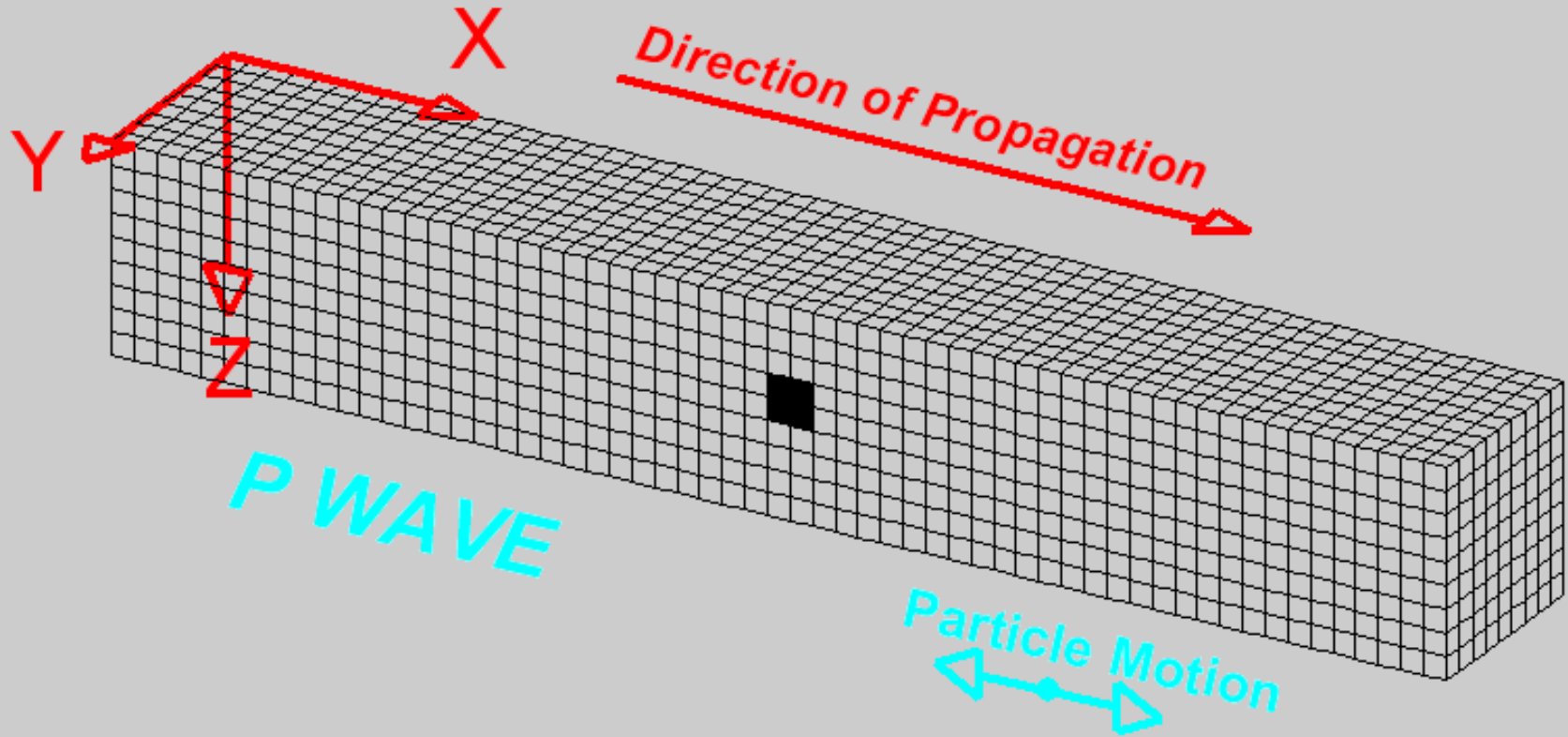
Body Waves

- There are two types of body waves
 - 1) P-Waves (Primary waves)
 - 2) S-Waves (Secondary waves)

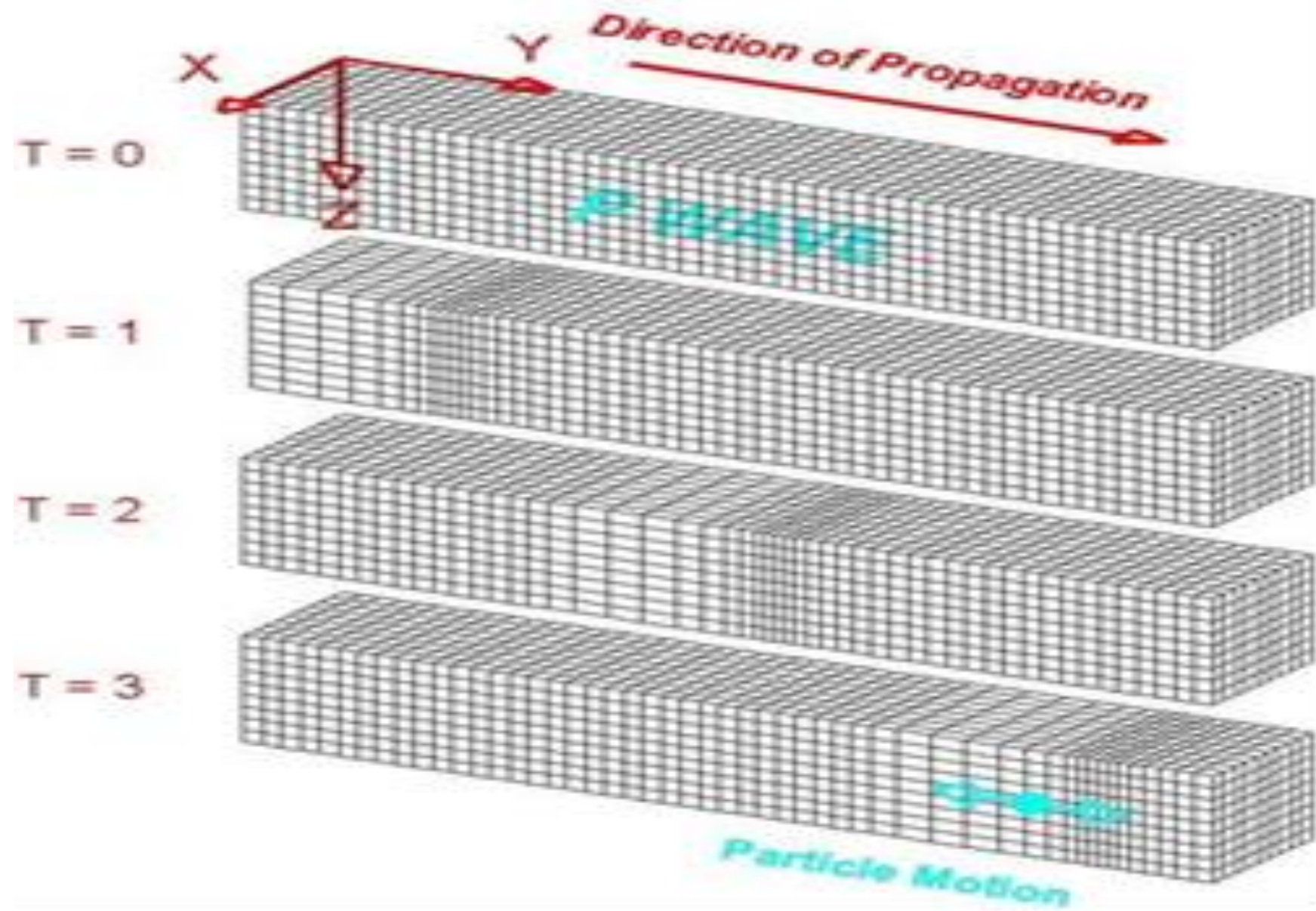
P-Waves

- **P waves** are longitudinal or compressional waves, which means that the ground is alternately compressed and dilated in the direction of propagation.
- These waves generally travel slightly less than twice as fast as S waves and can travel through any type of material.
- In air, these pressure waves take the form of sound waves, hence they travel at the speed of sound. Typical speeds are 330 m/s in air, 1450 m/s in water and about 5000 m/s in granite.
- P waves are sometimes called "primary waves",
- These are not as destructive as the S waves and surface waves that follow them.
- This is the fastest kind of seismic wave.

Compressional Wave (P-Wave)



Deformation propagates. Particle motion consists of alternating compression and dilation. Particle motion is parallel to the direction of propagation (longitudinal). Material returns to its original shape after wave passes.



P-Waves

- The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air.
- These waves travel at ~ 6 km/s near the surface to ~ 10.4 km/s near the Earth's core about 2900km below the surface.
- As the waves enter the core, the velocity drops to ~ 6 km/s increasing to ~ 11 km/s near the center.
- Sometimes animals can hear the P waves of an earthquake. Usually we only feel the bump and rattle of these waves.

Speed of P-Waves

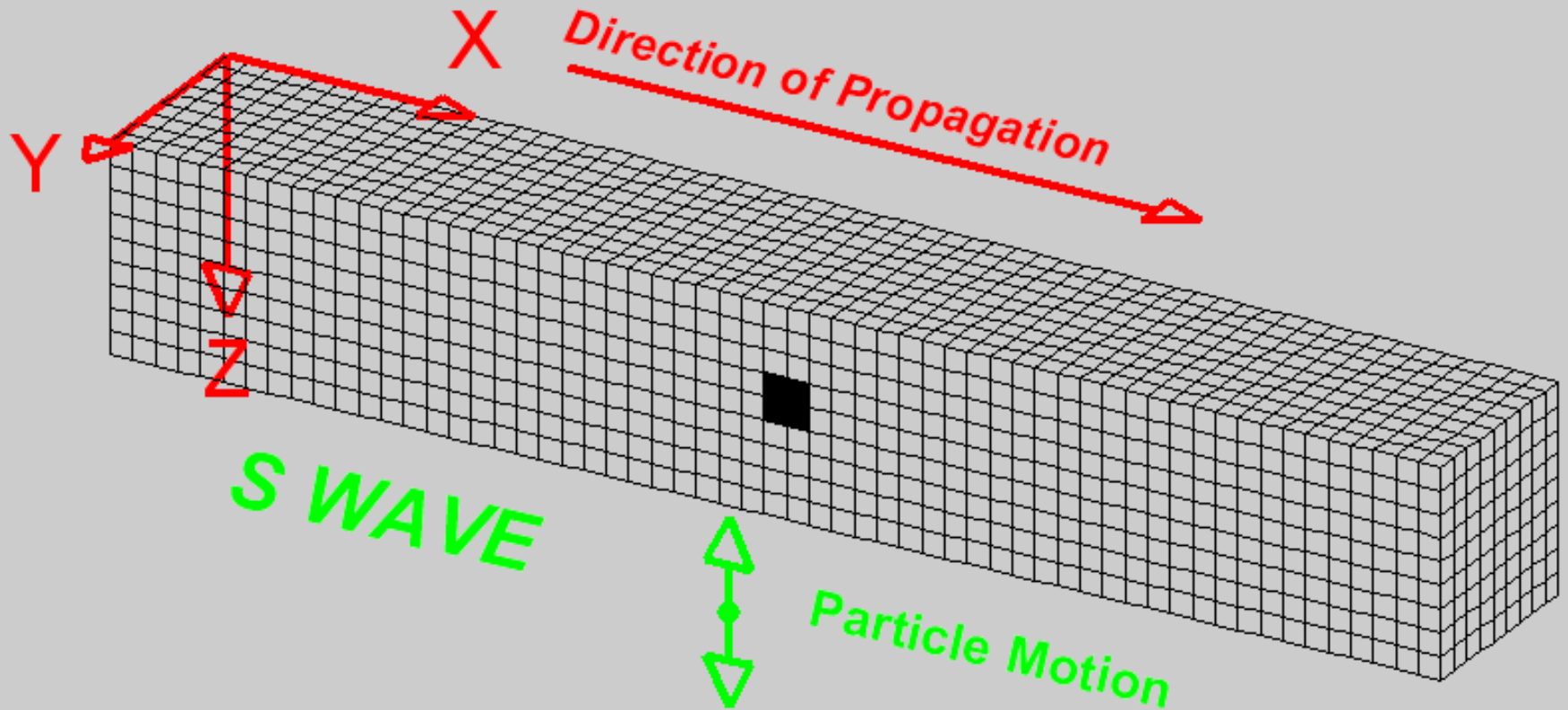
$$v_p = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}$$

- where K is the modulus of incompressibility, μ is the modulus of rigidity and ρ the density of the material through which the wave is propagating. Of these density shows the least variation so the velocity is mostly controlled by K and μ .

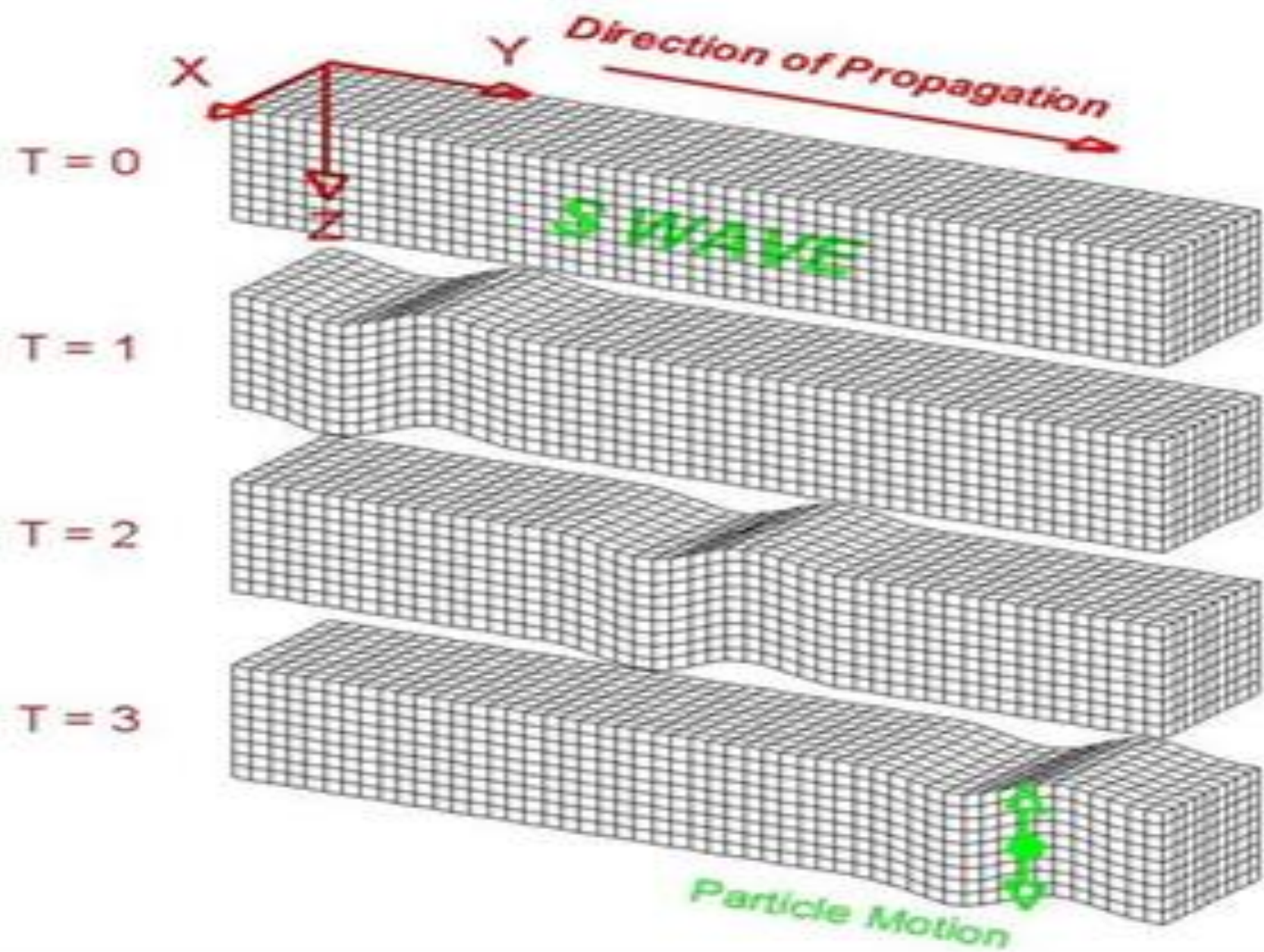
S-Waves

- **S waves** are transverse or shear waves, which means that the ground is displaced perpendicularly to the direction of propagation.
- S waves can travel only through solids, as fluids (liquids and gases) do not support shear stresses.
- Their speed is about 60% of that of P waves in a given material.
- S waves are sometimes called "secondary waves", and are several times larger in amplitude than P waves.

Shear Wave (S-Wave)



Deformation propagates. Particle motion consists of alternating transverse motion. Particle motion is perpendicular to the direction of propagation (transverse).



S-Waves

- **Secondary wave**, which is the second wave you feel in an earthquake. This wave moves rock up and down, or side-to-side
- Its name, S for secondary, comes from the fact that it is the second direct arrival on an earthquake [seismogram](#), after the [compressional](#) primary wave or P-wave

$$v_s = \sqrt{\frac{\mu}{\rho}}$$

S-Waves

- These waves travel from ~ 3.4 km/s near the surface to ~ 7.2 km/s near the boundary of the liquid core (Gutenberg discontinuity).
- These waves travel at a slower rate but with greater amplitude.

Surface Wave

- There are two major types of Surface waves as follows;
 - 1) Rayleigh waves
 - 2) Love waves

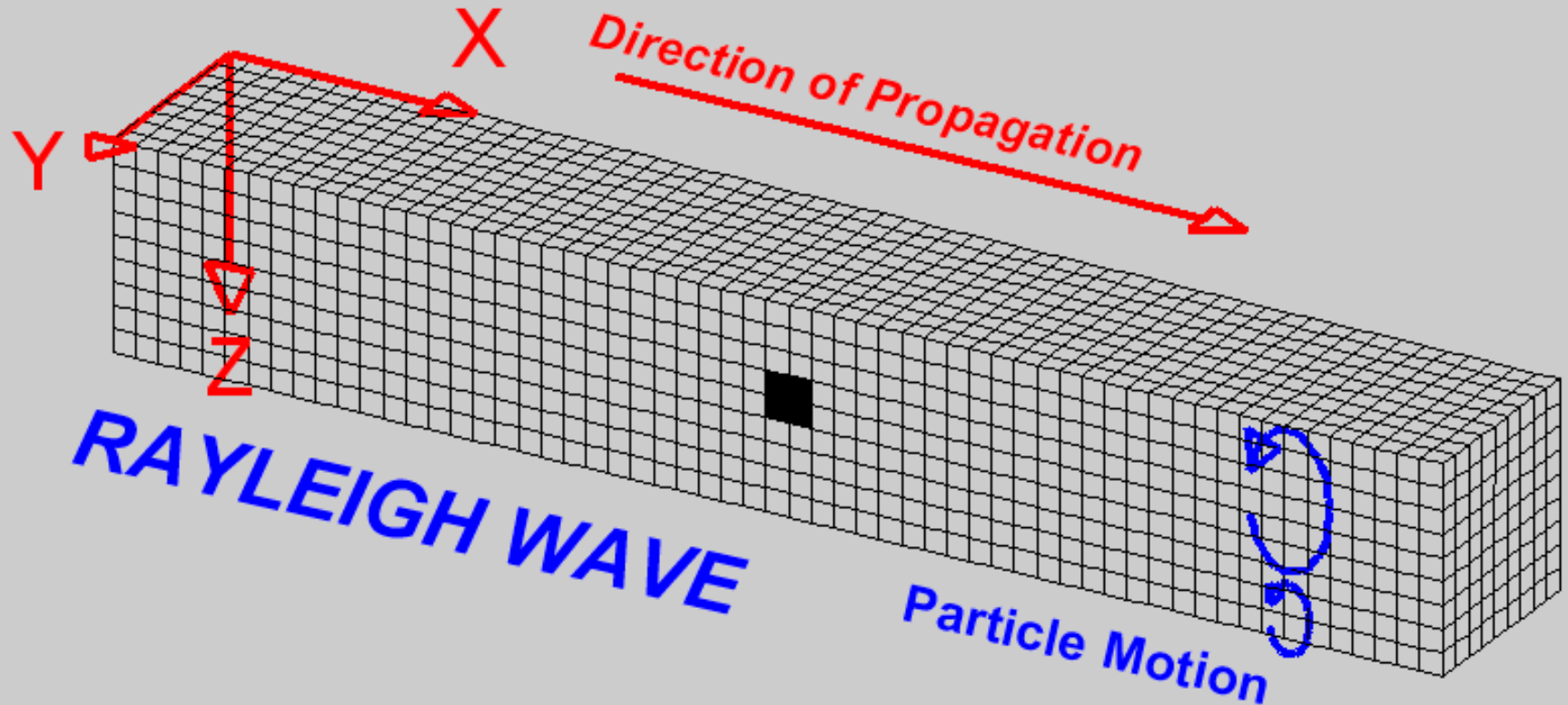
Rayleigh Waves

- **Rayleigh waves**, also called ground roll, are surface waves that travel as ripples similar to those on the surface of water.
- The existence of these waves was predicted by John William Strutt, [Lord Rayleigh](#), in [1885](#).
- They are slower than body waves, and supposedly can readily be seen during an earthquake in an open space like a parking lot where the cars move up and down with the waves.
- A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down, and side-to-side in the same direction that the wave is moving.

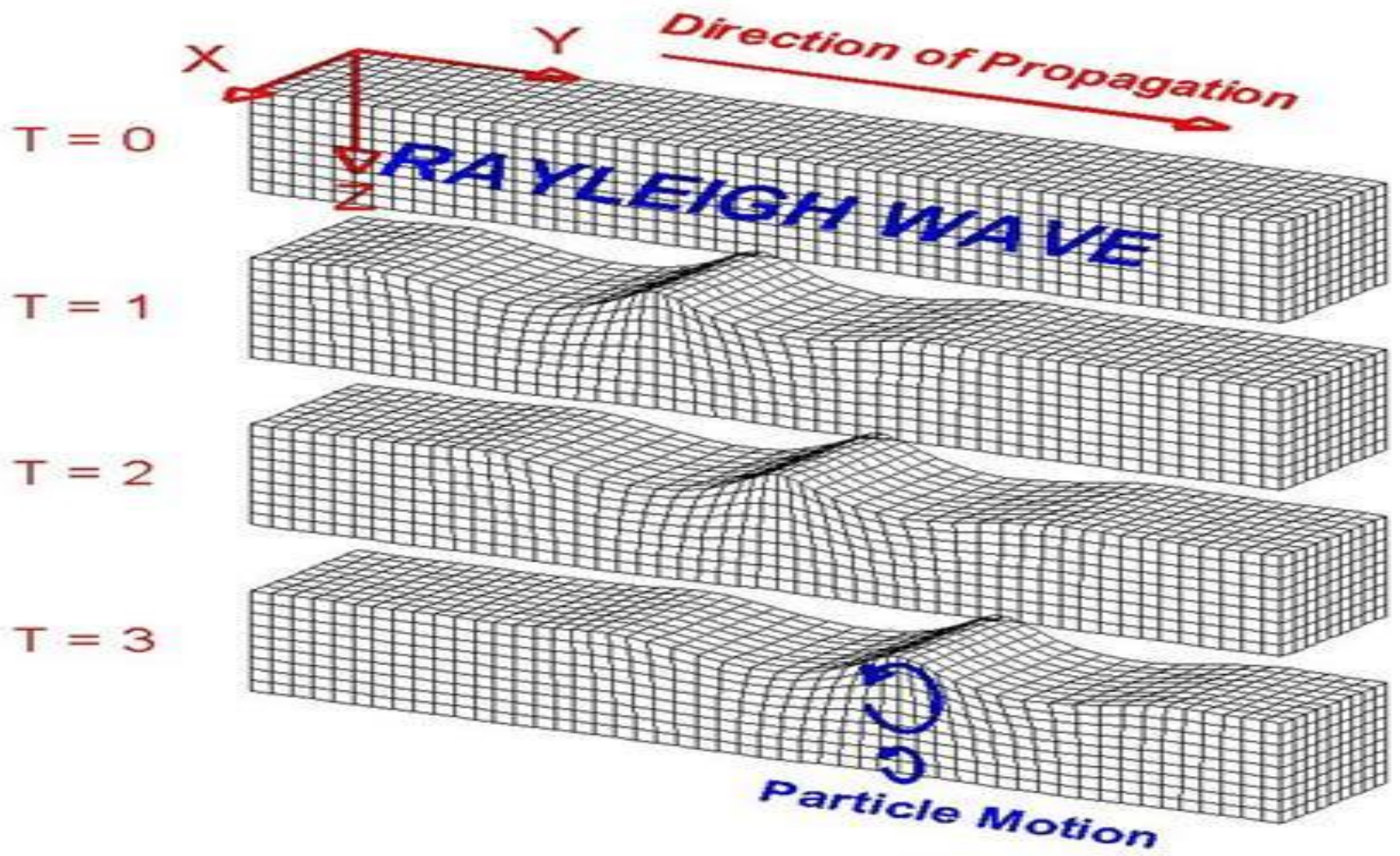
Rayleigh Waves

- Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.
- Since Rayleigh waves are surface waves, the strength, or [amplitude](#), of the waves decreases exponentially with the depth of the earthquake. However, since they are confined to the surface, their amplitude decays only as $\frac{1}{\sqrt{r}}$, where r is the distance the wave has traveled from the earthquake. Surface waves therefore decay more slowly with distance than do body waves, which travel in three dimensions.

Rayleigh Wave (R-Wave)

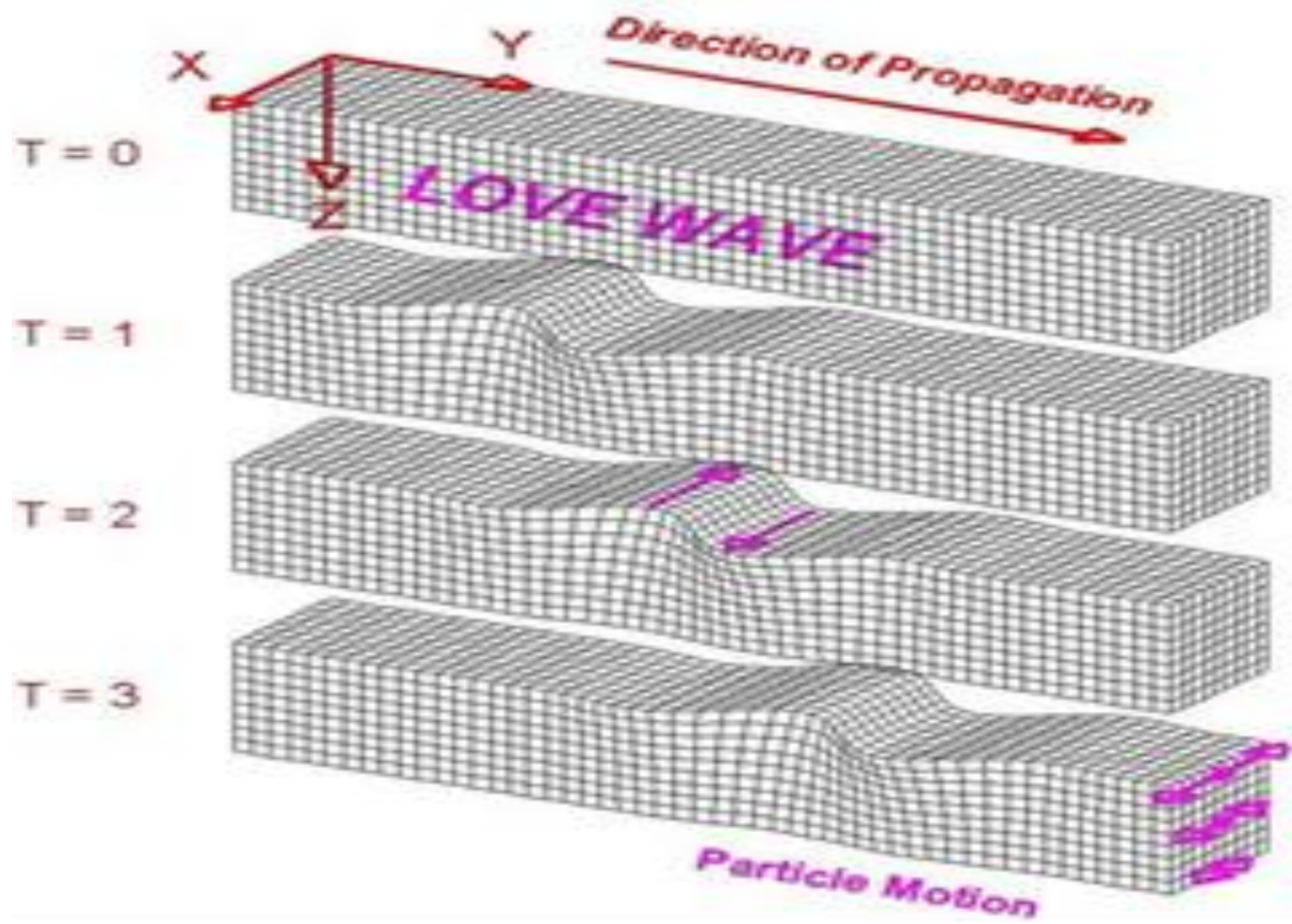


Deformation propagates. Particle motion consists of elliptical motions (generally retrograde elliptical) in the vertical plane and parallel to the direction of propagation. Amplitude decreases with depth. Material returns to its original shape after wave passes.

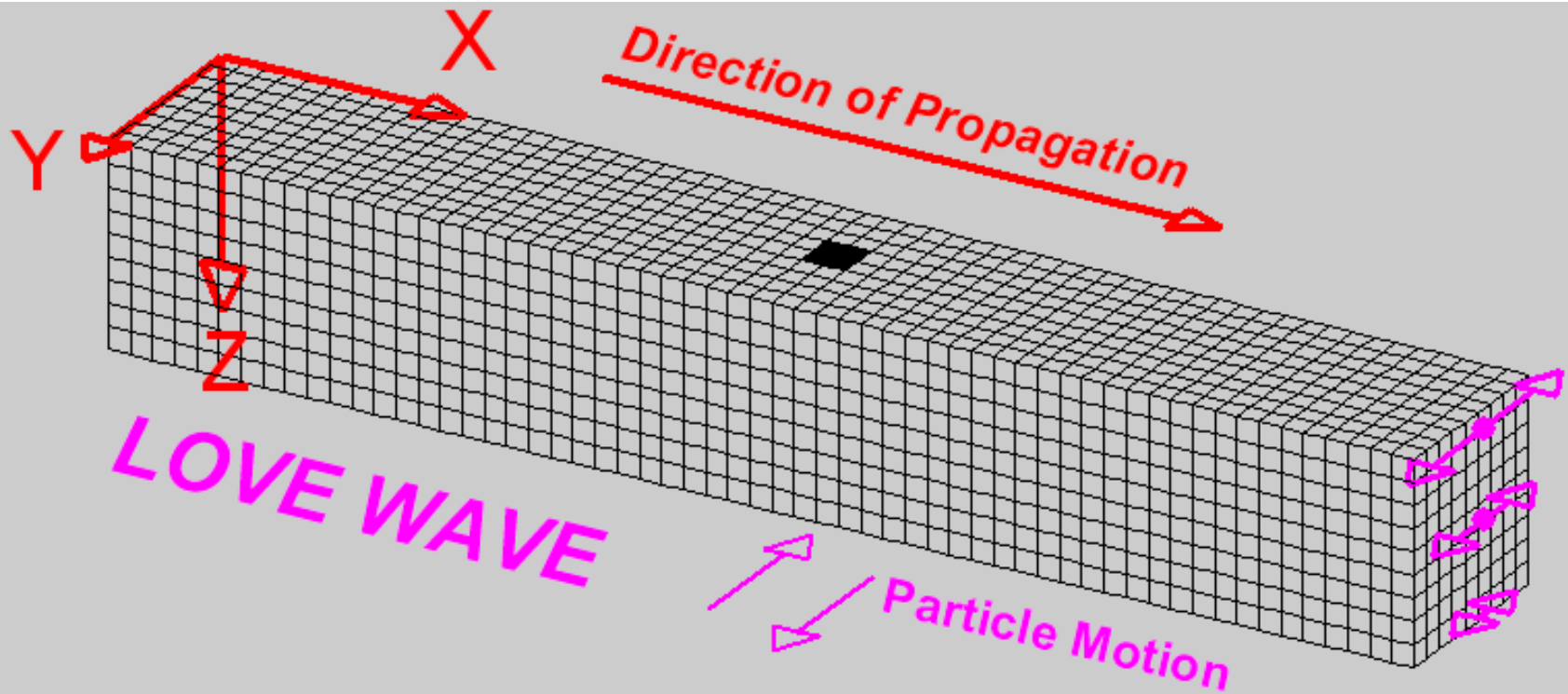


Love Waves

- **Love waves** are surface waves that cause horizontal shearing of the ground.
- They are named after [A.E.H. Love](#), a British mathematician who created a mathematical model of the waves in [1911](#).
- They usually travel slightly faster than Rayleigh waves.
- It's the fastest surface wave and moves the ground from side-to-side.



Love Wave (L-Wave)



Deformation propagates. Particle motion consists of alternating transverse motions. Particle motion is horizontal and perpendicular to the direction of propagation (transverse). To aid in seeing that the particle motion is purely horizontal, focus on the Y axis (red line) as the wave propagates through it. Amplitude decreases with depth. Material returns to its original shape after wave passes.

Basic Definitions

Earthquake

Earthquake is a natural phenomenon caused by the geological/tectonic actions in the faulted or ruptured rock. Large amount of energy is released in the form of elastic waves and cause disruption at the earth.

Seismology

Seismology is the science that study seismic waves and what the waves tell us about the structure of earth, physics of earthquakes, It is the primary means by which scientist learn about earth deep interior

Definitions

Earthquake Seismology

- Seismology is the science of earthquake related phenomenon comprising two sciences.
- Geology: Visible Earthquake phenomenon
- Geophysics: Invisible Earth quake waves of elastic disturbance behavior of matters under the influence of heat, temperature and pressure etc.

Focus (Hypocenter)

A point below the earth surface where first movement of earthquake begins. It is source of earthquake waves.

Epicenter

A point on the earth surface directly above the focus of an earthquake. It is most severely shaken spot due to earth quake.

Definitions

Seismograph

These are instrument to record the shock waves produced by the earthquake. It can record the horizontal and vertical movement. This is the setup of World Wide Standardized Seismograph Network. (WWSSN)

Seismogram

Record of earth quake measurements are called seismogram.

Meizoseismal

The area of strong shaking and damage.

Definitions

Main Shock

The largest shock of an earthquake.

After Shock

These are the shocks recorded after a sizable earthquake. These are also called settling shock.

Before Shock

An earthquake shock that occur before the largest or main shock.

Definitions

Fault

Fracture along which the movement have been occurred.

Fault creep

Slow movement along the faults allowing the continuous release of energy.

Intensity of Earthquake

It is the description of the physical damage cause by an earthquake i.e.; Mercalli scale.

Magnitude scale

Power of an earthquake recorded by a seismograph is called magnitude of earthquake. It is measured by Richter scale.

Definitions

Attenuation

- Decrease in the amplitude of the seismic waves with distance due to geometric spreading, energy absorption and spreading.

Capable Fault

- An active fault that is just capable of producing macro Earthquake. This fault must exhibit one or more of the following characteristics.
- Movement at or near the ground surface at least once within the past 35000 years.
- Macro seismicity 3.5 magnitude or greater.
- A structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other.

Definitions

Maximum credible earthquake

- The Earthquake associated with specific seismotectonic structure, source area or provinces that would cause the most severe vibratory ground motion or foundation dislocation capable of being produced at the site under the currently known tectonic framework. It is determined by the judgment based on all known regional and local geological and seismological data.

Operating basis Earthquake

- The Earthquake for which the structure is designed to resist and remain operational. It may be determined on a probabilistic basis considering the regional and local geology and seismology and reflex the level of EQ protection desired for operational or economic reasons. OBE is usually taken as a EQ producing the maximum motions at the site once in hundred years.

Definitions

Design Earthquakes

- It define the ground motion at the site of the structure and form the basis for dynamic response analysis.

Seismotectonic province

- A geographic area characterize by a combination of geology and seismic history.

EQ Cycle

- Concept that seismicity follows a cyclic pattern with repetition of similar events after every several hundred to thousands years depending on the region.