Introduction to Earthquake Engineering
Lec#1

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List of Content

- **Introduction,**
- **Earthquake magnitude & intensity,**
- **importance of ground conditions,**
- **Nature of seismic forces,**

Definition of Earthquake

- **Earthquake**
- a sudden violent shaking of the ground, typically causing great destruction, as a result of movements within the earth's crust or volcanic action.
- Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to propel objects and people into the air, and wreak destruction across entire cities.

Definition of Earthquake

- **Seismicity**

- **Seismicity** of an area is the frequency, type, and size of earthquakes experienced over a particular time period. The word tremor is also used for non-earthquake seismic rumbling

Definition of Earthquake

- **Earthquake Magnitude**
- Earthquake magnitude is a measure of the "size," or amplitude, of the seismic waves generated by an earthquake source and recorded by seismographs.
- Measurement of the "size" of an earthquake in terms of amount of
- energy released.

Definition of Earthquake

- **<u>Earthquake Magnitude</u>**
- Various scales have been used to define magnitude. These include;
- 1. Local magnitude scale, ML
- 2. Surface wave magnitude, Ms
- 3. Body wave magnitude, m
- 4. Moment magnitude, Mw or M
- There are empirical equations that can be used to convert between the various magnitude scales. However, moment magnitude is now the accepted "standard" magnitude used by seismologists.

Definition of Earthquake

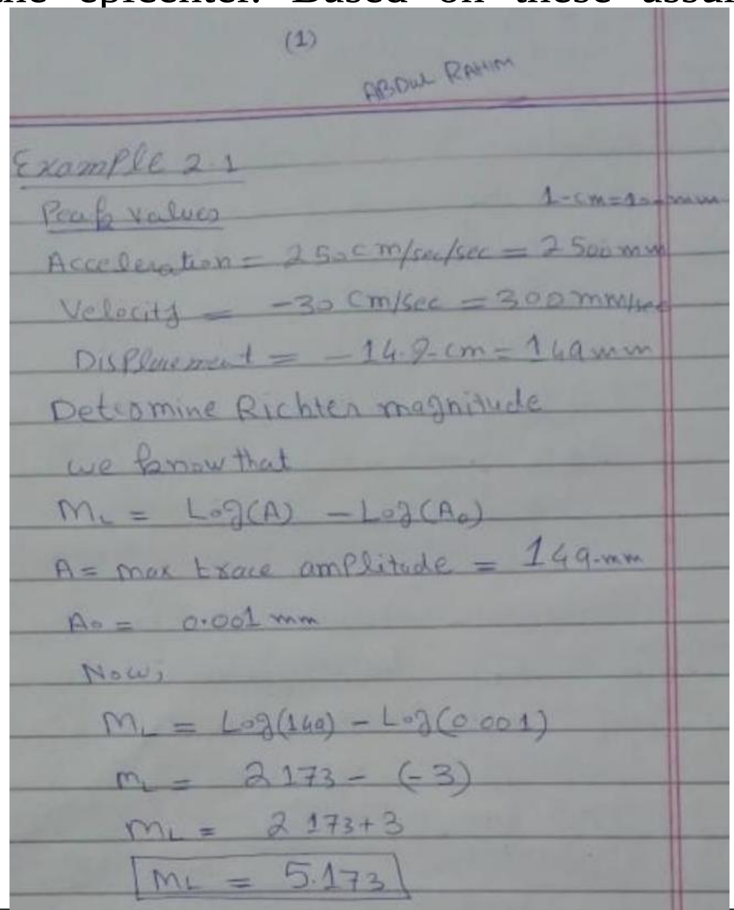
- **Local magnitude scale, ML**

ML = log A - log A0 = log A/A0 (Richter 1935, 1958)

- Where;
- **ML** = local magnitude (Richter magnitude scale)
- **A** = maximum trace amplitude (mm) as recorded by a standard Wood-Anderson seismograph that has a natural period of 0.8 s, a damping factor of 80%, and a static magnification of 2800. It must be that amplitude that would be recorded if a Wood-Anderson seismograph were located on firm ground at a distance of exactly 100 km from the epicenter. Charts and tables are available to adjust the value of A for the usual case where the seismograph is not located exactly 100 km from the epicenter.
- **Ao = 0.001 mm.** The zero of the local magnitude scale was arbitrarily fixed as an amplitude of 0.001 mm, which corresponded to the smallest earthquakes then being recorded.

Definition of Earthquake

- **Example:**
- Displacement measured from a standard Wood-Anderson seismograph is 14.9 cm and that the instrument is exactly 100 km from the epicenter. Based on these assumptions, determine the Richter magnitude.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ABDUL RAHIM

Example 2.1

Peak values — 1 cm = 10 mm

Acceleration = 250 cm/sec/sec = 2500 mm

Velocity = 30 cm/sec = 300 mm/sec

Displacement = 14.9 cm = 149 mm

Determine Richter magnitude

we know that

$M_L = Log(A) - Log(A_0)$

A = max trace amplitude = 149 mm

A_0 = 0.001 mm

Now;

$M_L = Log(149) - Log(0.001)$

$M_L = 2.173 - (-3)$

$M_L = 2.173 + 3$

$M_L = 5.173$

Definition of Earthquake

- **Surface wave magnitude, Ms**

- The scale is based on measurement of low-frequency Rayleigh waves (≈ 0.05 Hz. / Period of 20s) at distances > 1000 km. Used to measure sizes of shallow (< 70 km deep), distant earthquakes.

$$Ms = \log A' + 1.66 \log \Delta + 2.0$$

- Ms = surface wave magnitude scale
- A′ = maximum ground displacement, □m
- Δ = epicentral distance to seismograph measured in degrees (360° corresponds to the circumference of earth)

Definition of Earthquake

Example: Assume that a seismograph, located 1200 km from the epicenter of an earthquake, records a maximum ground displacement of 15.6 mm for surface waves having a period of 20 seconds. Determine the surface wave magnitude.

Example 2.2

Siesmograph location = 1200 km

max Ground displacement = 15.6 mm

Period = 20 sec

Surface wave magnitude = Ms = ?

Solution:-

Circumfrence of Earth = $(4\times10^7)(360^\circ)$ m

Distance to Siesmograph = 1.2×10^6 m

$\Delta = \frac{1.2\times10^6}{4\times10^7}\times360^\circ = 0.03\times360^\circ$

$\Delta = 10.8^\circ$

Convert max Ground displacement to μm

$A' = 15.6\,mm = 15.6\times1000$ $\quad 1\,mm = 1000\,\mu m$

$A' = 15600\,\mu m$

Now,

$M_s = \log(A') + 1.66\log(\Delta) + 2.0$

$M_s = \log(15600) + 1.66\log(10.8^\circ) + 2$

$M_s = 4.193 + 1.66(1.033) + 2$

$M_s = 4.193 + 1.714 + 2$

$M_s = 7.907$

Definition of Earthquake

- **Body Wave Magnitude**
- Measured at distances > 2000 km from epicenter measures frequencies of ≈1- 2 Hz.
- Long period body wave magnitude, mB and Short period body wave magnitude, mb

Definition of Earthquake

- **Moment Magnitude Scale, Mw or M**
- More commonly used method for determining the magnitude of large earthquakes because it tends to take into account the entire size of the earthquake.

Mw = 0.67 log M0 – 6.0

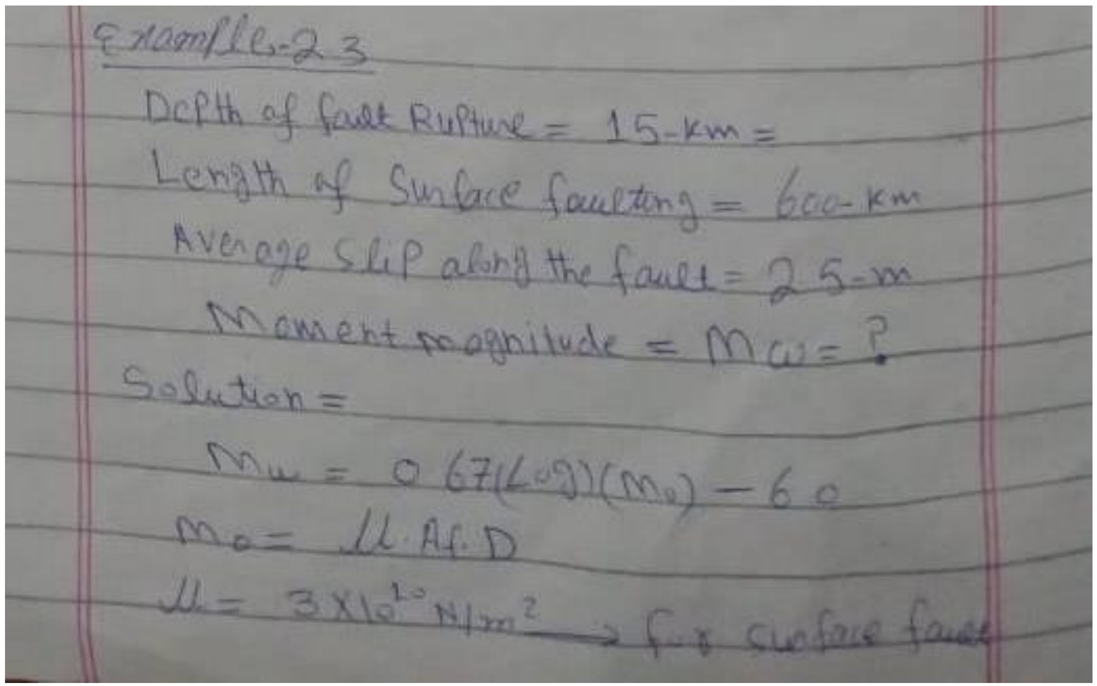
- M0 = seismic moment = μ . Af . D (N-m)
- μ = shear modulus of material along fault plane (N/m2)
- (approx. 3x1010 N/m2 for surface crust and 7x1012 N/m2 for mantle)
- Af = area of fault plane undergoing slip (m2)

(estimated as the length of surface rupture times the depth of the aftershocks)

- D = average displacement of ruptured segment of fault (m)

Definition of Earthquake

- **Example:** Assume that during a major earthquake, the depth of fault rupture is estimated to be 15 km, the length of surface faulting is determined to be 600 km, and the average slip along the fault is 2.5 m. Determine the moment magnitude.



Example-2.3

Depth of fault Rupture = 15-km =

Length of Surface faulting = 600-km

Average Slip along the fault = 2.5-m

Moment magnitude = M_w = ?

Solution =

$M_w = 0.67(Log)(M_o) - 6.0$

$M_o = \mu \cdot A_f \cdot D$

$\mu = 3 \times 10^{10}\ N/m^2$ → for surface fault

Definition of Earthquake

A_f = Area of fault plan undergoing slip =
= Depth of fault X Length of surface fault

$A_f = 15 \times 600 = 9000\ km^2 = 9 \times 10^9\ m^2$

D = Average slip = 2.5 m

Now:

$M_0 = \mu A_f D = 3 \times 10^{10} \times 9 \times 10^9 \times 2.5$

$M_0 = 675 \times 10^{19} = 6.75 \times 10^{20}$ (N-m)

Now,

$M_w = 0.67 \, Log(M_0) - 6.0$

$M_w = 0.67 \, Log(6.75 \times 10^{20}) - 6.0$

$M_w = 0.67(20.829) - 6.0$

$M_w = 13.955 - 6.0$

$M_w = 7.955$

Richter scale of earthquake magnitude

magnitude level	category	effects	earthquakes per year
less than 1.0 to 2.9	micro	generally not felt by people, though recorded on local instruments	more than 100,000
3.0–3.9	minor	felt by many people; no damage	12,000–100,000
4.0–4.9	light	felt by all; minor breakage of objects	2,000–12,000
5.0–5.9	moderate	some damage to weak structures	200–2,000
6.0–6.9	strong	moderate damage in populated areas	20–200
7.0–7.9	major	serious damage over large areas; loss of life	3–20
8.0 and higher	great	severe destruction and loss of life over large areas	fewer than 3

Definition of Earthquake

- **Earthquake Intensity**

- The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures.

- Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. There are many intensities for an earthquake, depending on where you are, unlike the magnitude, which is one number for each earthquake.

Definition of Earthquake

- **<u>Earthquake Intensity</u>**
- **Intensity of Damage:** Quantification of the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale of "I" through "XII", with " I" denoting not felt, and "XII" total destruction.
- The values will differ based on the distance to the earthquake, with the highest intensities being around the epicentral area. Data is gathered from individuals who have experienced the quake, and an intensity value will be given to their location.

The Modified Mercalli Intensity Scale

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few 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.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings 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.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	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	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

- The lower numbers of the intensity scale generally deal with the manner in which the earthquake is felt by people.
- The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above.

Factors That Determine the Impact of an Earthquake

- **Severity**
- **Location:**
- **Magnitude**
- **Depth**
- **Distance from the epicenter**
- **Local geologic conditions**
- **Development (Building type, quality etc)**

Factors That Determine the Impact of an Earthquake

- **Severity**
- Some earthquakes are just bigger than others. In fact, earthquakes hit the United States every single day, but most are too small to notice. We know they occur because of seismographs, sensitive devices that detect tremors in the ground, and the application of the Richter scale, which rates earthquakes on a scale of 1 to 10. The most severe earthquake ever recorded was in Valdivia, Chile, in 1960 and registered at 9.5 on the Richter scale, though, strictly speaking, the scale doesn't have an end point.

Factors That Determine the Impact of an Earthquake

- **Location**
- This one is kind of obvious—an earthquake that hits in a populated area is more likely to do damage than one that hits an unpopulated area or the middle of the ocean.
- **Depth**
- Earthquakes can happen anywhere from at the surface to 700 kilometers below. In general, deeper earthquakes are less damaging because their energy dissipates before it reaches the surface.

Factors That Determine the Impact of an Earthquake

- **<u>Distance from the epicenter</u>**
- The epicenter is the point at the surface right above where the earthquake originates and is usually the place where the earthquake's intensity is the greatest.
- **<u>Local Ground Condition</u>**
- The nature of the ground at the surface of an earthquake can have a profound influence on the level of damage. Loose, sandy, soggy soil, like in Mexico City, can liquefy if the shaking is strong and long enough, for example. That doesn't bode well for any structures on the surface.

Factors That Determine the Impact of an Earthquake

- **Development (Building type, quality etc)**
- **Population density.**

How soil type affects earthquake damage

- An earthquake’s effects vary with the softness of the sediment. As seismic waves travel through the ground, they move faster through hard rock than soft soil. When waves transition from hard to soft earth, they increase in amplitude (or size).
- A bigger wave causes stronger shaking.
- The same principle also applies to sediment thickness. The deeper the sediment layer above bedrock, the more soft soil there is for the seismic waves to travel through. Soft soil means bigger waves and stronger amplification.

Soil type and site classifications

- The National Earthquake Hazards Reduction Program (NEHRP) defined six different site classifications, based on the type of soil and rock in the area and their shear-wave velocity:1

A: hard rock (igneous rock).

B: rock (volcanic rock).

C: very dense soil and soft rock (sandstone).

D: stiff soil (mud).

E: soft soil (artificial fill).

F: soils requiring site-specific evaluations.

Soil type and site classifications

- The earlier in the alphabet, the harder the soil. Site class A soil is hardest and results in the least wave amplification. Site class E soil is the opposite — the softest soil with the most amplification. Site class F could contain a few types of soil, such as those vulnerable to potential failure during an earthquake, peat or some clays.
- Although soil type is a significant predictor of an earthquake's effects, it's not the only factor. Other characteristics — like the fault's orientation, irregularities in the rupturing fault surface, and dispersion of waves as they hit subsurface structures — can create spots of significant damage, and those hot spots are unique to each earthquake.

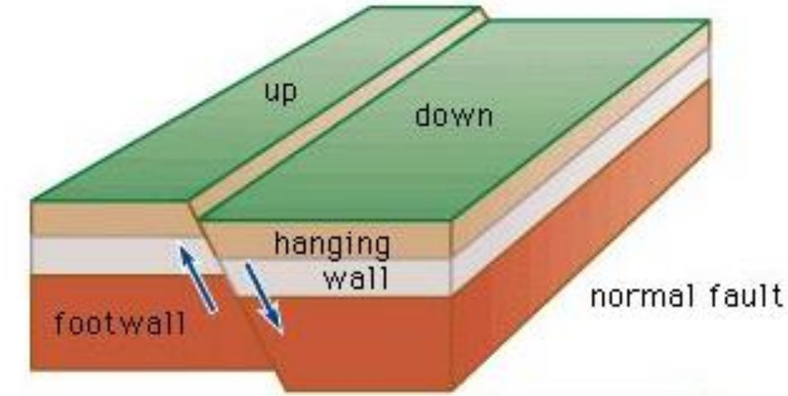
Nature of Seismic Forces

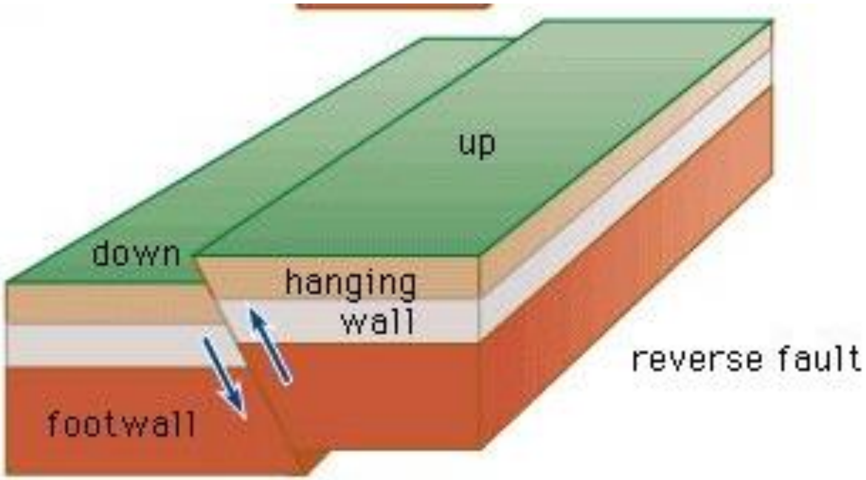
- Earthquakes are caused by the sudden release of energy within some limited region of the rocks of the Earth. The energy can be released by elastic strain, gravity, chemical reactions, or even the motion of massive bodies. Of all these the release of elastic strain is the most important cause, because this form of energy is the only kind that can be stored in sufficient quantity in the Earth to produce major disturbances. Earthquakes associated with this type of energy release are called tectonic earthquakes.

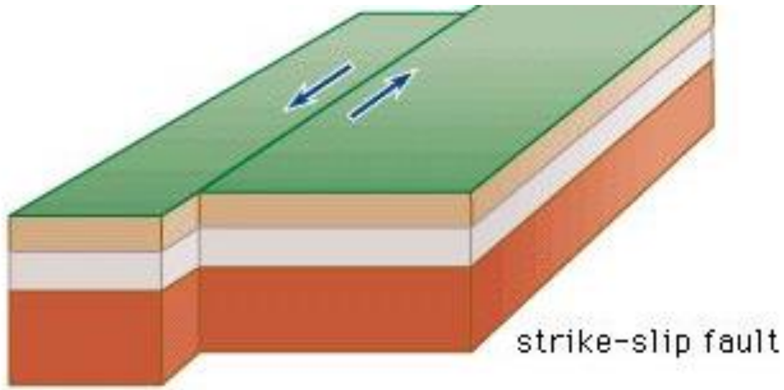
Nature of Seismic Forces

- **Faults**
- Cracks along which rocks slip are called faults; these may break through the ground surface, or remain deep within the earth.
- **Normal Fault.** In a normal fault, the block above the fault moves down relative to the block below the fault. This fault motion is caused by tensional forces and results in extension.
- **Reverse Fault.** In a reverse fault, the block above the fault moves up relative to the block below the fault. This fault motion is caused by compression forces and results in shortening. A reverse fault is called thrust fault if the dip of the fault plane is small.
- **Strike-Slip Fault.** In a strike-slip fault, the movement of blocks along a fault is horizontal. The fault motion of a strike-slip fault is caused by shearing forces.

Nature of Seismic Forces



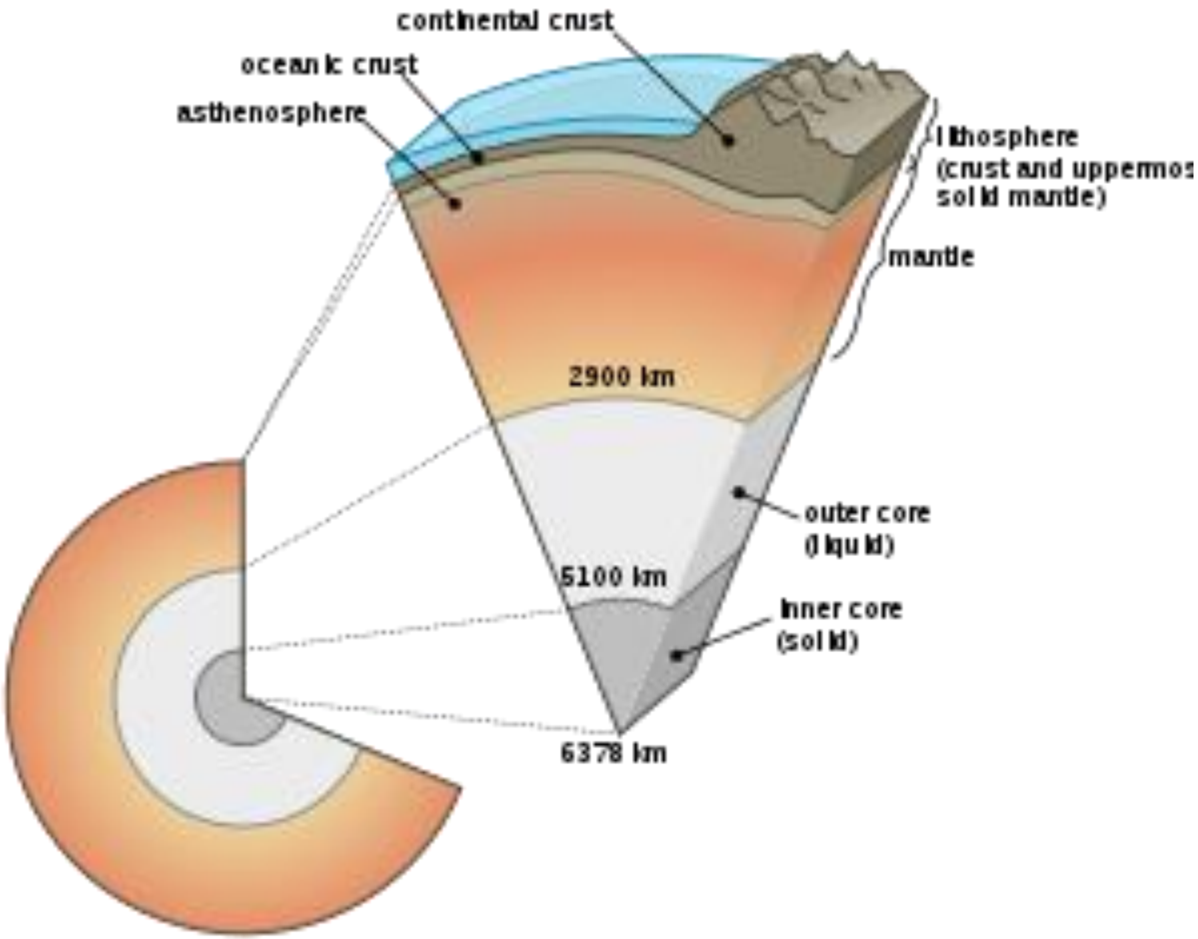




Nature of Seismic Forces

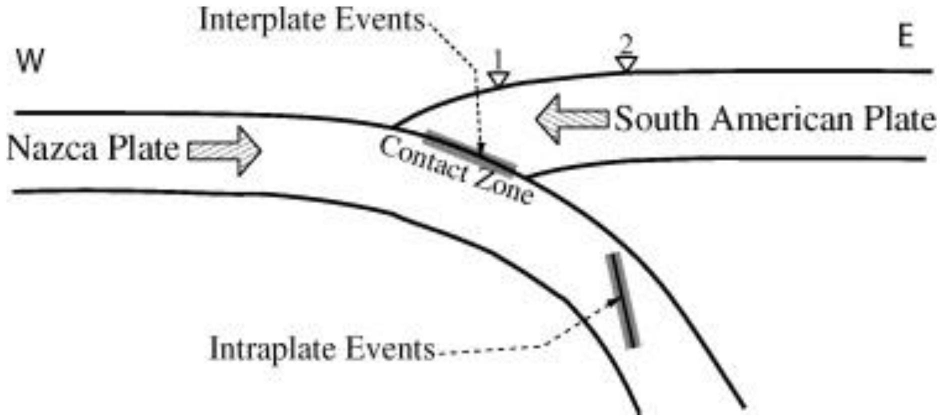
- **<u>Tectonic Plates</u>**
- Stress that causes an earthquake is created by a movement of almost rigid plates, called tectonic plates, which fit together and make up the outer shell of the Earth (also called Earth's crust).
- These plates float on a dense, liquid layer beneath them. The plates move at such a slow rate (approximately the same rate as a fingernail grows) that the motion is not perceptible.

Nature of Seismic Forces



Nature of Seismic Forces

- Earthquakes occur most frequently on or near the edges of the plates where stress is most concentrated; such earthquakes are called **interplate** (Between Plates)earthquakes.
- However, a significant number of earthquakes, including some large and damaging ones, do occur within the plates; these earthquakes are known as **intraplate (Within Plate)** earthquakes.



Nature of Seismic Forces

- Types of INTER-PLATE Interactions:
  - Convergent: Two plates collides head to head (and mountains are formed).
  - Divergent: Two plates move away from one another (and rifts are created).
  - Transform: Two plates move side-by-side, along the same direction or in opposite directions.

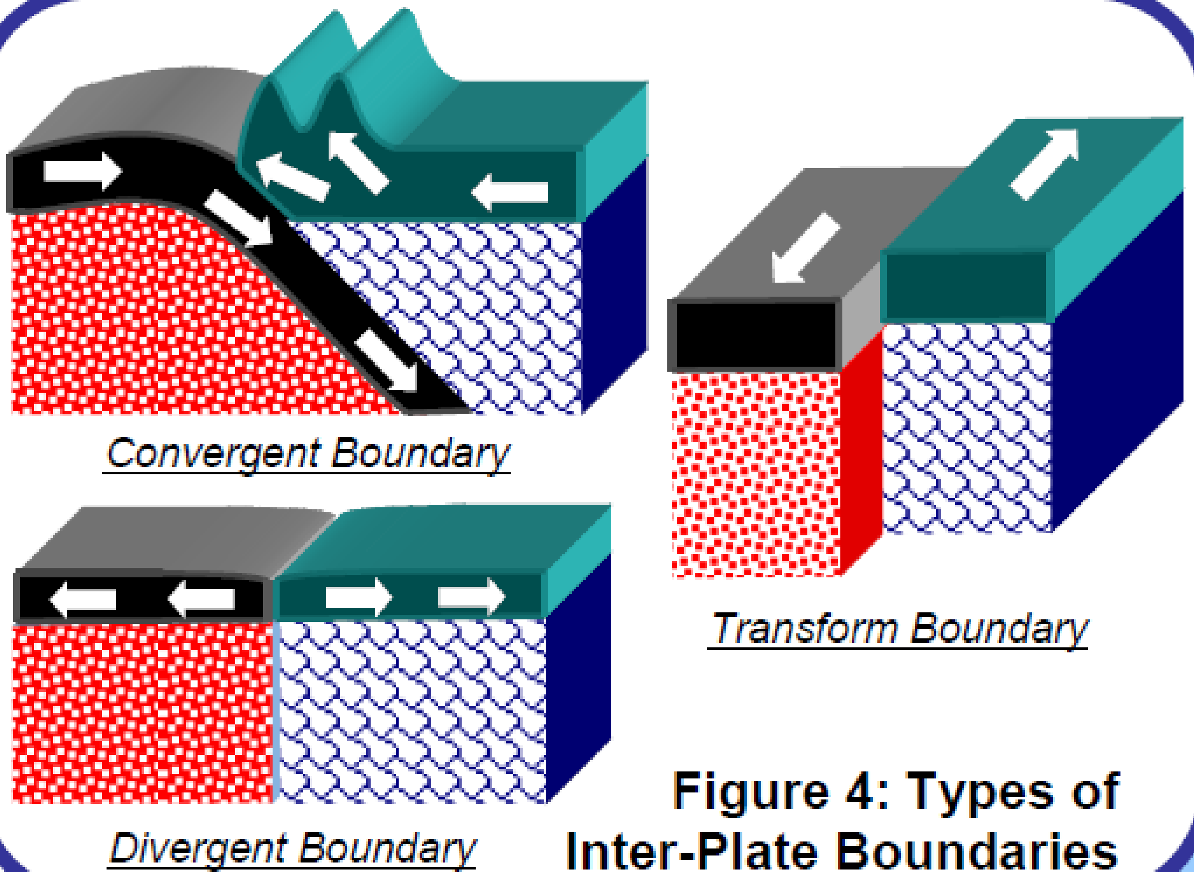


Figure 4: Types of Inter-Plate Boundaries

Causes of Earthquake

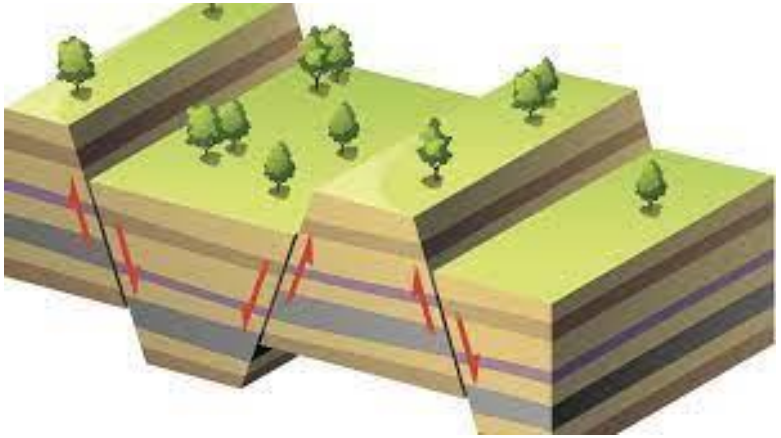
- The main causes of earthquakes fall into five
- **Volcanic Eruptions**
- **Tectonic Movements**
- **Geological Faults**
- **Man-Made**
- **Minor Causes**

Causes of Earthquake

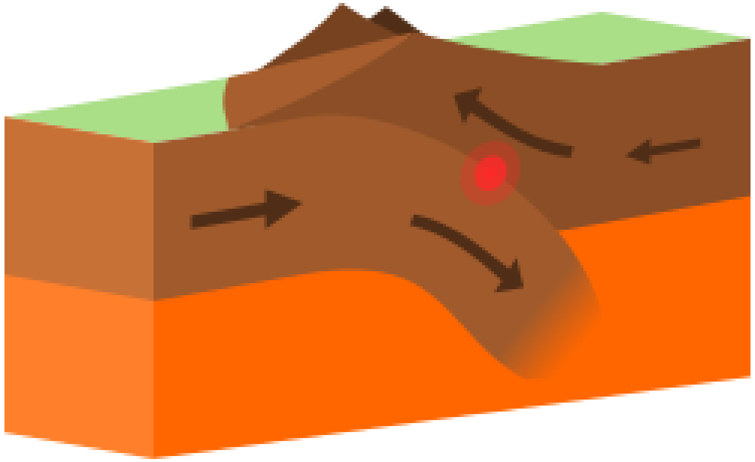
- **Volcanic Eruptions**
- The main cause of the earthquake is volcanic eruptions. Such type of earthquakes occurs in areas, with frequent volcanic activities. When boiling lava tries to break through the surface of the earth, with the increased pressure of gases, certain movements caused in the earth's crust. Movement of lava beneath the surface of the earth can also cause certain disruptions. This sends shockwaves through the earth, causing damage. These earthquakes are mild. Their range is also limited. However, there have been certain exceptions, with volcanic earthquakes bring havoc and death to thousands of people.

Causes of Earthquake

- **Tectonic Movements**
- The surface of the earth consists of some plates, comprising of the upper mantle. These plates are always moving, thus affecting the earth's crust. These movements categorized into three types: constructive, destructive, and conservative. Constructive is when two plates move away from each other, they correspond to mild earthquakes. When two plates move towards each other and collide, this is known as destructive plate boundaries. This is very destructive. Conservative corresponds to passing by of plates of crust. Earthquakes of this type have varying intensities.



Tectonic Movements

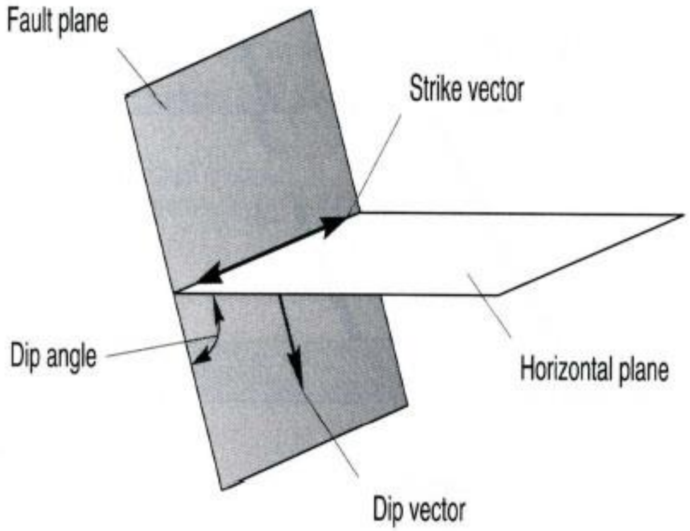


Causes of Earthquake

- **Geological Faults**
- A fault is defined as a fracture or a zone of fractures in rock along which displacement has occurred.
- A geological fault is known as the displacement of plates of their original plane. The plane can be horizontal or vertical. These planes are not formed suddenly but slowly develop over a long period. The movement of rocks along these planes brings about tectonic earthquakes. These faults occur due to the impact of geological forces. The displacement of plates creates the fracturing of rocks, which releases a lot of energy. This type of earthquake can be disastrous.

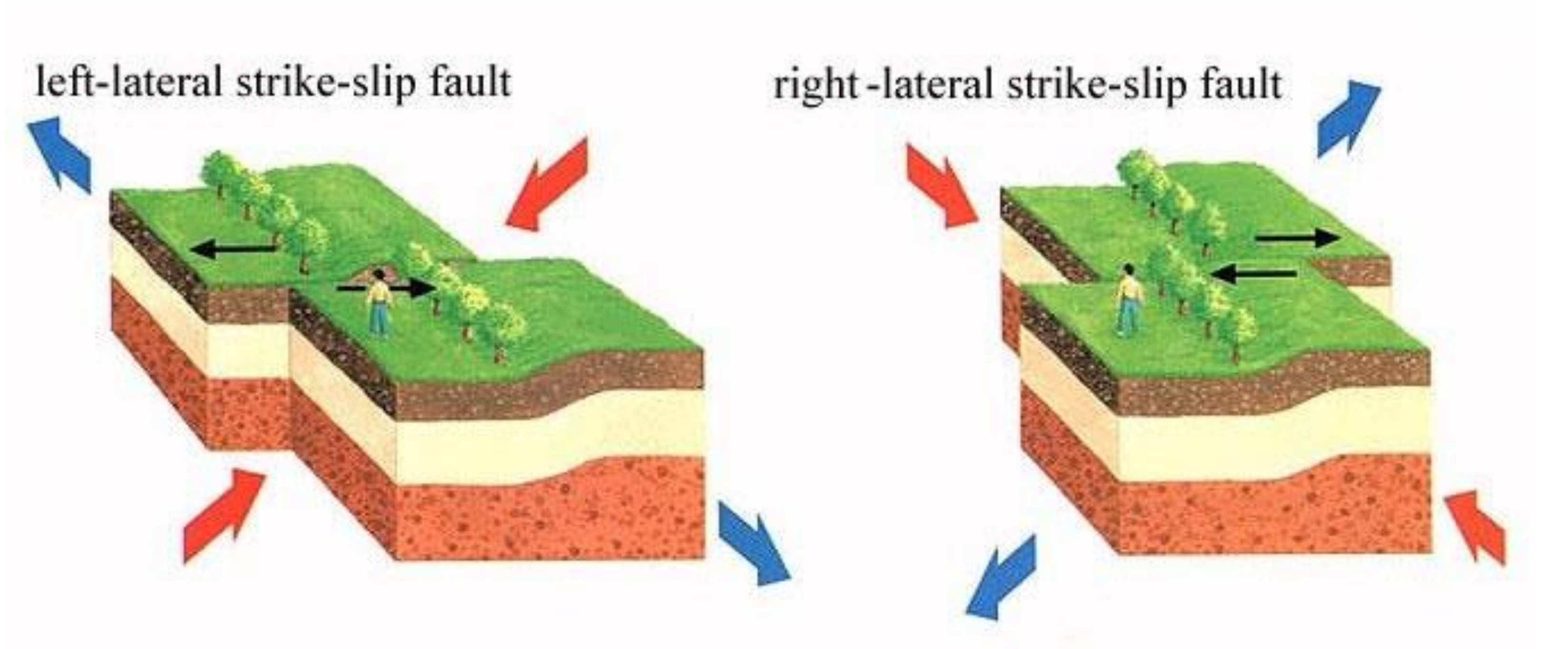
Causes of Earthquake

- **Strike and Dip**
- The “strike” is the compass heading of a horizontal line drawn on the fault plane.
- The “dip” is measured in a direction perpendicular to the strike and is the angle between the inclined fault plane and a horizontal plane (0o-90o).



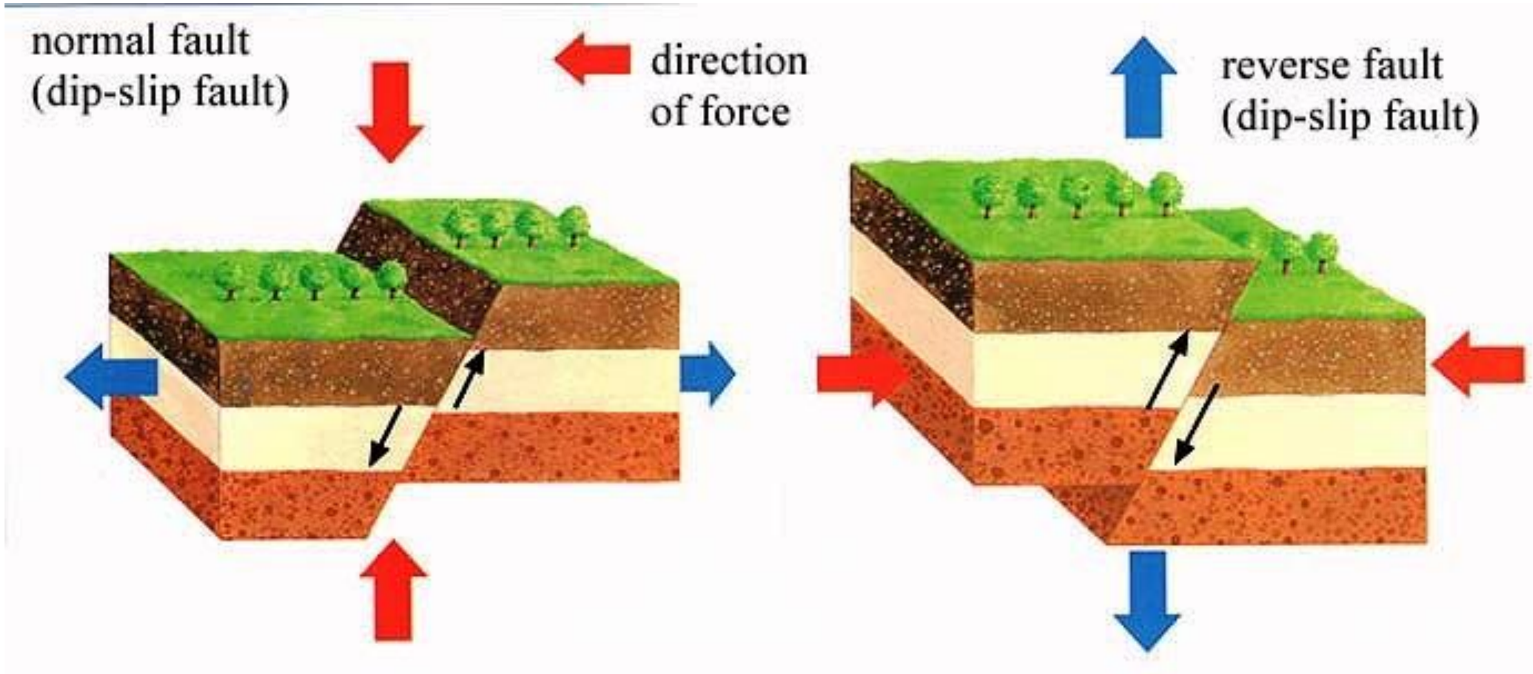
Causes of Earthquake

- **Types of Fault**
- **Strike-slip fault** (Transform fault) The fault movement is parallel to the strike (e.g. San Andreas fault)



Causes of Earthquake

- **<u>Types of Fault</u>**
- **Dip-Slip Fault:** The fault movement is in the direction of dip (perpendicular to the strike)

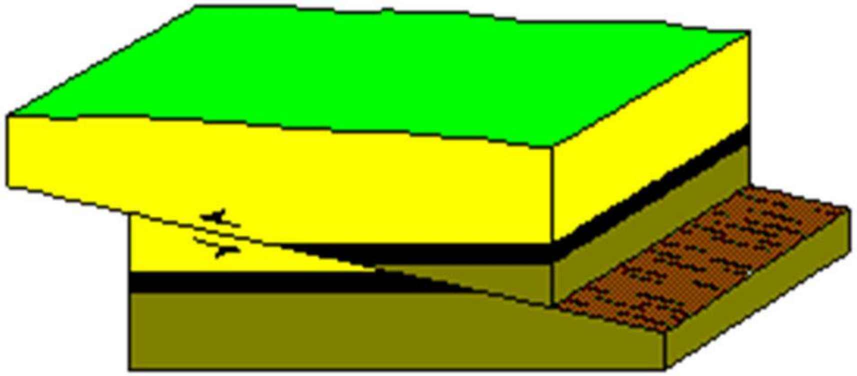


Causes of Earthquake

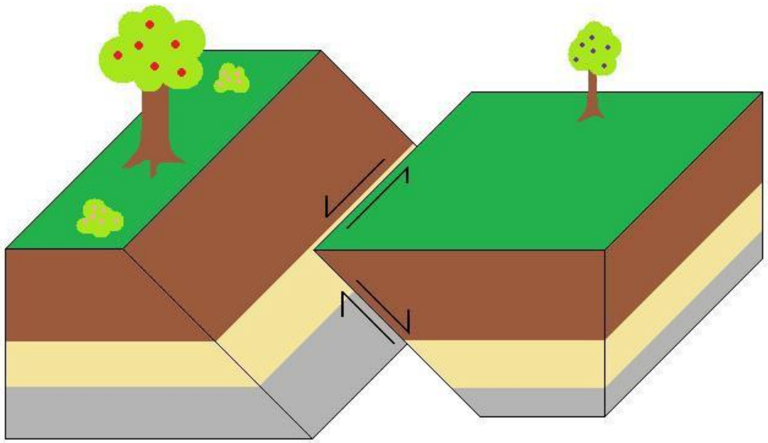
- **Types of Fault**
- **Normal fault:** The Hangingwall moves downward relative to the Footwall. Normal faulting is associated with tensile stresses in the crust and results in the horizontal lengthening of the crust.
- When the horizontal component of the dip slip movement is compressive, a **reverse fault** takes place. This results in a horizontal shortening of the crust.

Causes of Earthquake

- **Types of Fault**
- **Thrust fault:** When the dip of a reverse fault is less than or equal to
- **Oblique-slip fault:** When a fault experiences slip in both dip and strike directions.



THRUST FAULT



Oblique-slip fault: Arrows represent relative movement.

Geological Faults

Causes of Earthquake

- **Man-Made**
- The interference of man with nature can also become a cause of the earthquake. The disturbance of crustal balance due to heavy clubbing of water in dams can cause earthquakes. Nuclear bombing can send specific types of shockwaves throughout the surface of the earth, which can disturb the natural alignment of tectonic plates. Mining can also cause disturbance due to the extensive removal of rocks from different areas.

Causes of Earthquake

- **Minor Causes**
- Some minor causes such as landslides, avalanches, the collapse of heavy rocks, etc. can also cause minor shockwaves. The gases beneath the surface of earth contract and expand, giving rise to movements in plates beneath the crust. The plutonic earthquake occurs because of adjustments in rock beds in the interior of the earth’s crust. All these factors correspond to minor earthquakes, but sometimes these can also vary to moderate earthquakes.

landslides

THANK YOU!