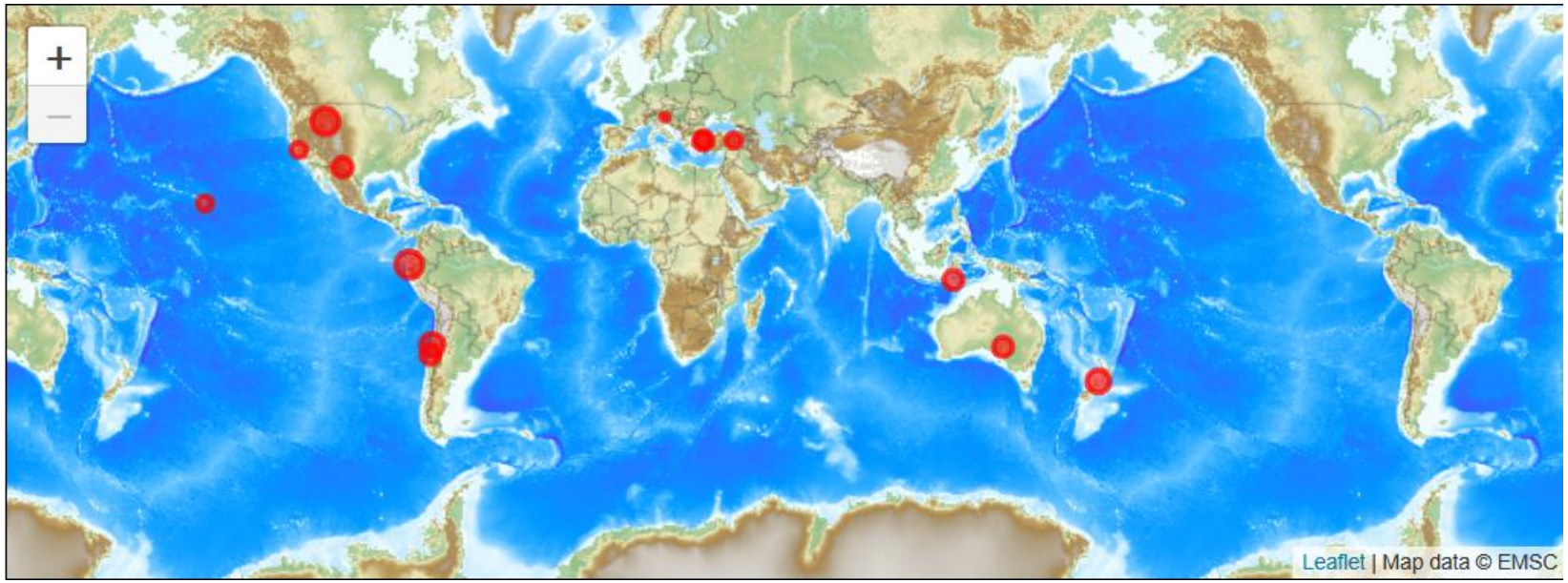
Earthquake

- Elements: Focus – Epicenter – Seismic waves - Seismology
- Global Distribution of Earthquake
- Earthquake Distribution in India

Dr. R Jegankumar
Professor and Head, Geography
Bharathidasan University, Tiruchirappalli



https://www.emsc-csem.org/

2025-11-10 01:23:48 6 min ago	31.637	-104.46	5	2.6	WESTERN TEXAS
2025-11-10 01:17:01 13 min ago	39.162	28.230	13	2.3	WESTERN TURKEY
2025-11-10 01:16:56 13 min ago	8.390	125.88	12	3.2	MINDANAO, PHILIPPINES
2025-11-10 01:10:23 19 min ago	39.136	28.226	13	2.2	WESTERN TURKEY
2025-11-10 01:08:34 21 min ago	39.392	39.107	5	2.0	EASTERN TURKEY
2025-11-10 01:08:17 21 min ago	36.585	-121.03	1	2.0	CENTRAL CALIFORNIA
2025-11-10 00:34:00 56 min ago	-8.300	120.43	11	2.6	FLORES REGION, INDONESIA
2025-11-10 00:31:46 58 min ago	-2.770	-79.84(	63	3.4	NEAR COAST OF ECUADOR
2025-11-10 00:16:30 1 hr 13 min ago	45.782	13.935	6	0.9	SLOVENIA
2025-11-10 00:16:11 1 hr 14 min ago	-33.96(	-72.33(	7	2.7	OFFSHORE O'HIGGINS, CHILE
2025-11-10 00:01:49 1 hr 28 min ago	-41.69(	173.37	63	3.0	SOUTH ISLAND OF NEW ZEALAND
2025-11-10 00:01:12 1 hr 29 min ago	-31.64(	138.67	7	2.5	SOUTH AUSTRALIA
2025-11-10 00:00:58 1 hr 29 min ago	44.796	-110.84	5	3.3	YELLOWSTONE NAT. PARK, WYOMING

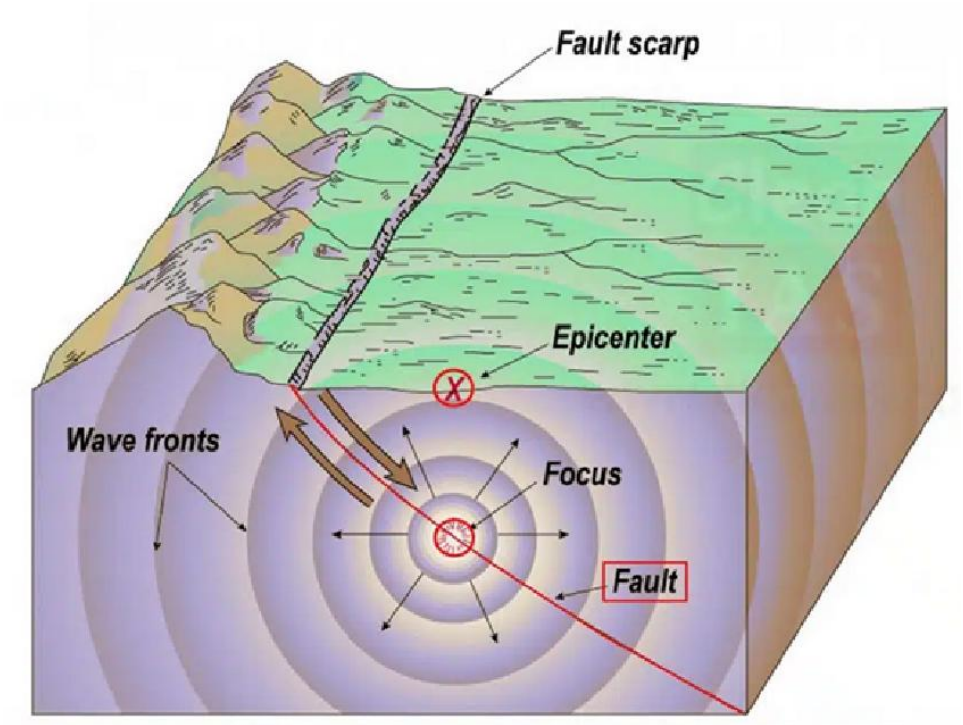
Earthquake

- An **earthquake** is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth‘s lithosphere that creates seismic waves.
- Earthquake is the form of energy of wave motion transmitted through the surface layer of the earth.
- It may be due to **faulting , folding, plate movement, volcaninc eruptions** and anthropogenic factors like **dams and reservoirs**.
- Earthquake are by far the most unpredictable and highly distructive of all the natural disasters.
- Minor **earth tremors** caused by gentle waves of vibration within the earth’s crust occur every few minutes while **Major earthquakes usually caused by movement along faults**, can be very disastrous particularly in densely populated areas

Focus and Epicenter

The point within Earth where faulting begins is the **focus, or hypocenter**.

The point directly above the focus on the surface is the **epicenter**. The intensity of the earthquake is highest at the epicenter and decreases with distance from the epicenter.



Terminology

- ✓ *Earthquake intensity*
- ✓ *Earthquake magnitude*
- ✓ *Richter Scale*
- ✓ *Mercalli Scale*
- ✓ *Fault*
- ✓ *Focus*
- ✓ *Epicenter*
- ✓ *Seismic wave*
- ✓ *Seismograph*

Measuring earthquakes

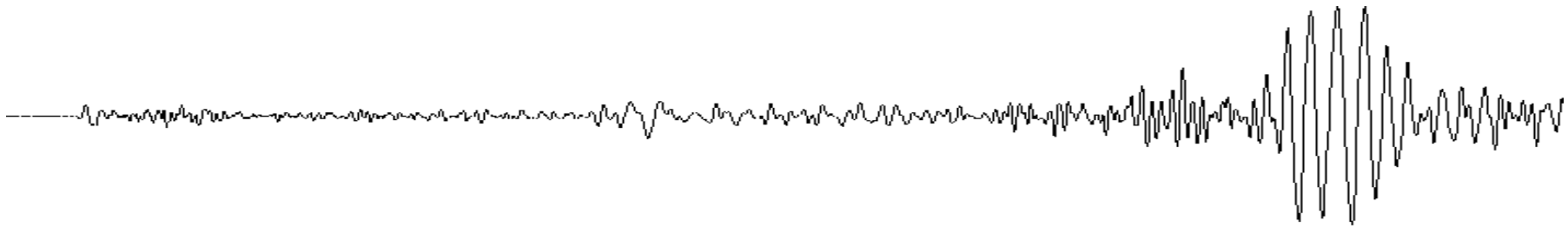
Seismometers are the instruments that are used to measure the motion of the ground, which includes those seismic waves generated by earthquakes, volcanic eruptions, and other seismic sources.

A Seismograph is also another term used to mean seismometer though it is more applicable to older instruments.

The recorded graphical output from a seismometer/seismograph is called as a **seismogram**. (Note: Do not confuse seismograph with seismogram. A seismograph is an instrument while a seismogram is the recorded output)

There are two main scales used in the seismometers:

(1) the Mercalli Scale and (2) the Richter Scale.



Mercalli Scale

The scale represents the **intensity** of the earthquake by analyzing the after-effects like how many people felt it, how much destruction occurred etc.
The range of intensity is from 1-12.

Richter Scale

This scale was devised by **Charles. F. Richter** in the year 1935.
The number indicating magnitude **ranges between 0 to 9**
The scale represents the **magnitude** of the earthquake.
Each whole number increase in the Richter scale represents a tenfold increase in the power of an earthquake.

Classification of earthquake

Causative factors

1. Natural

1. Volcanic
2. Tectonic
3. Isostatic
4. Plutonic

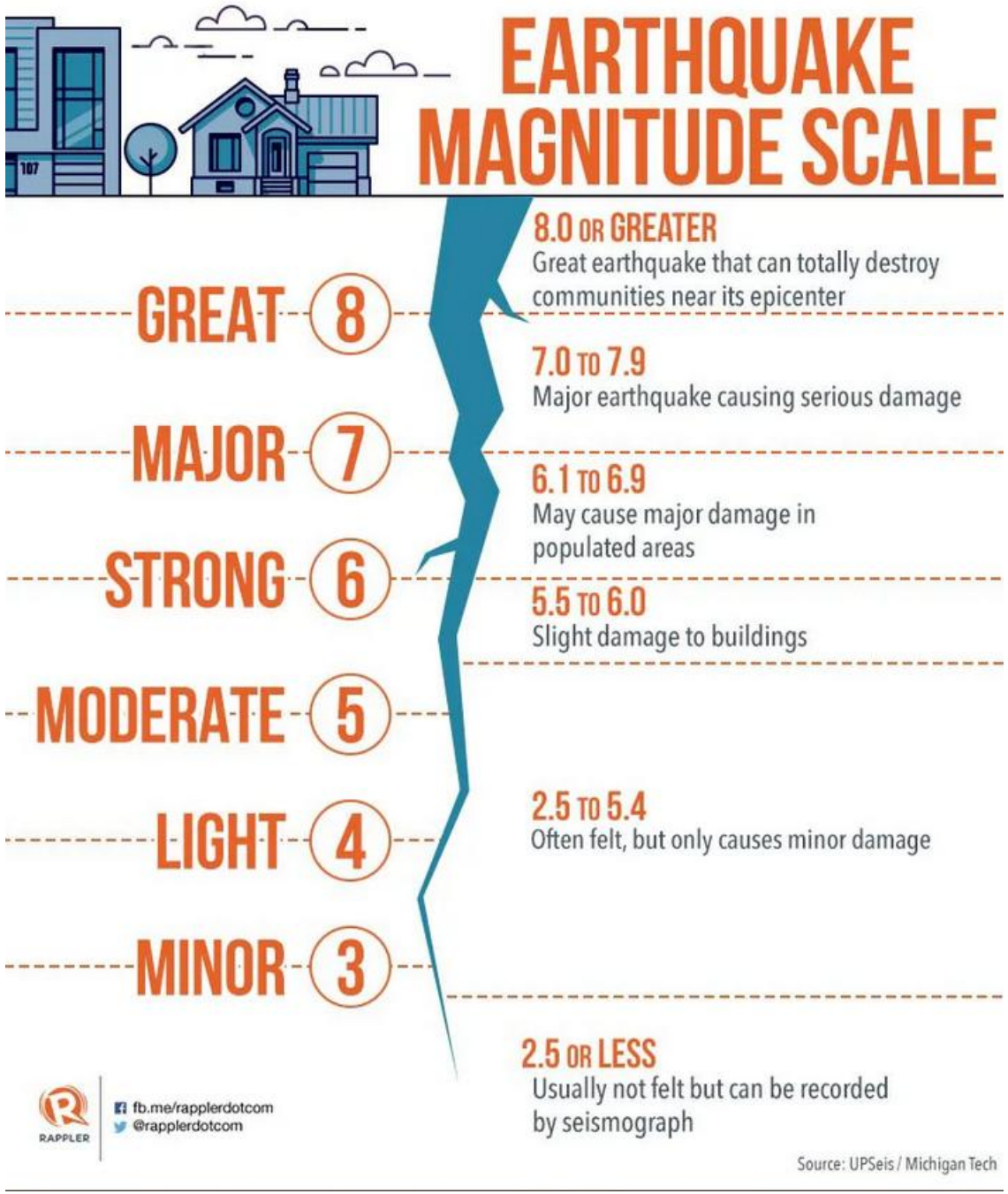
2. Artificial

Depth of focus

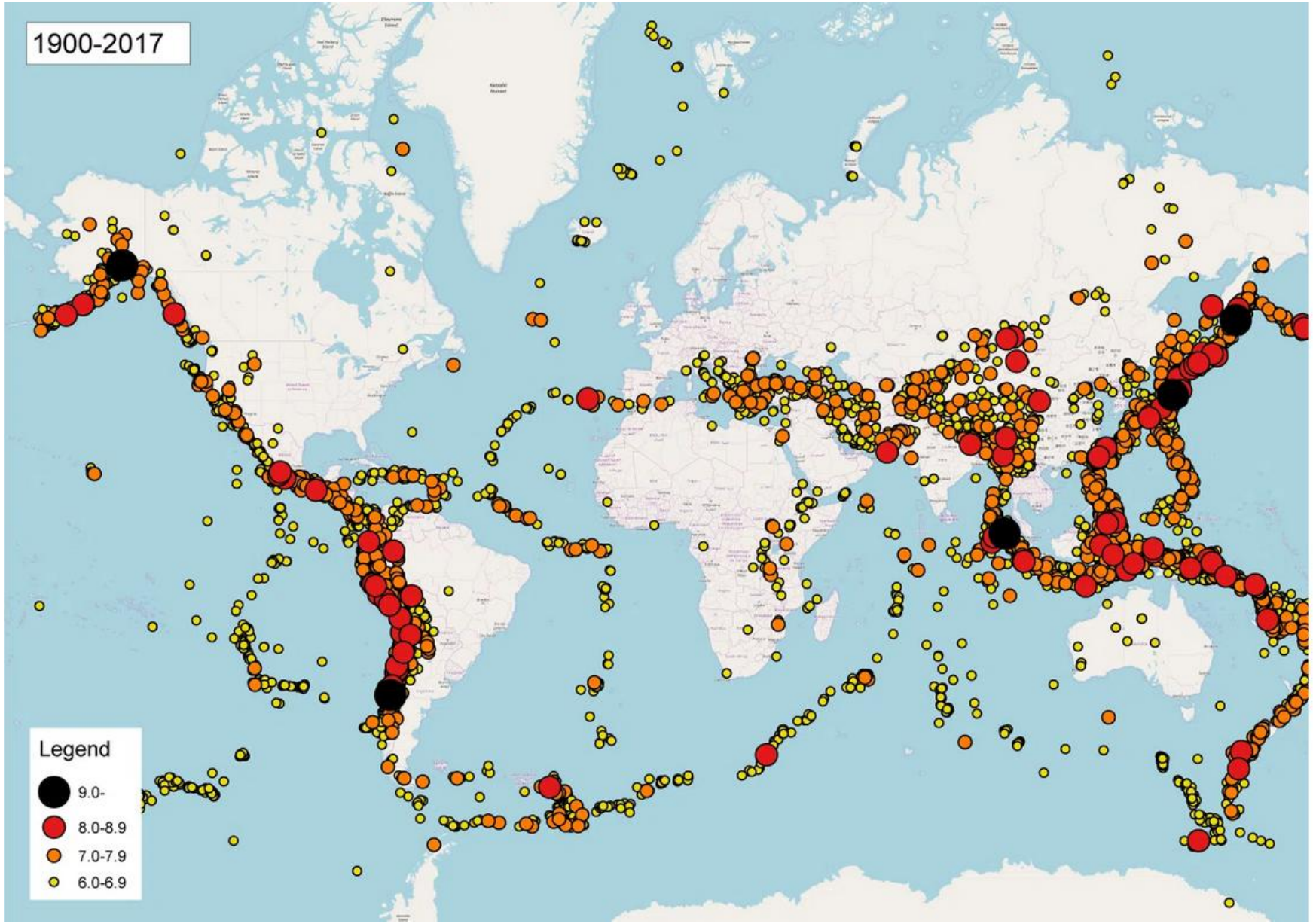
1. Moderate(0-50km)
2. Intermediate(50-250km)
3. Deep focus(250-700km)

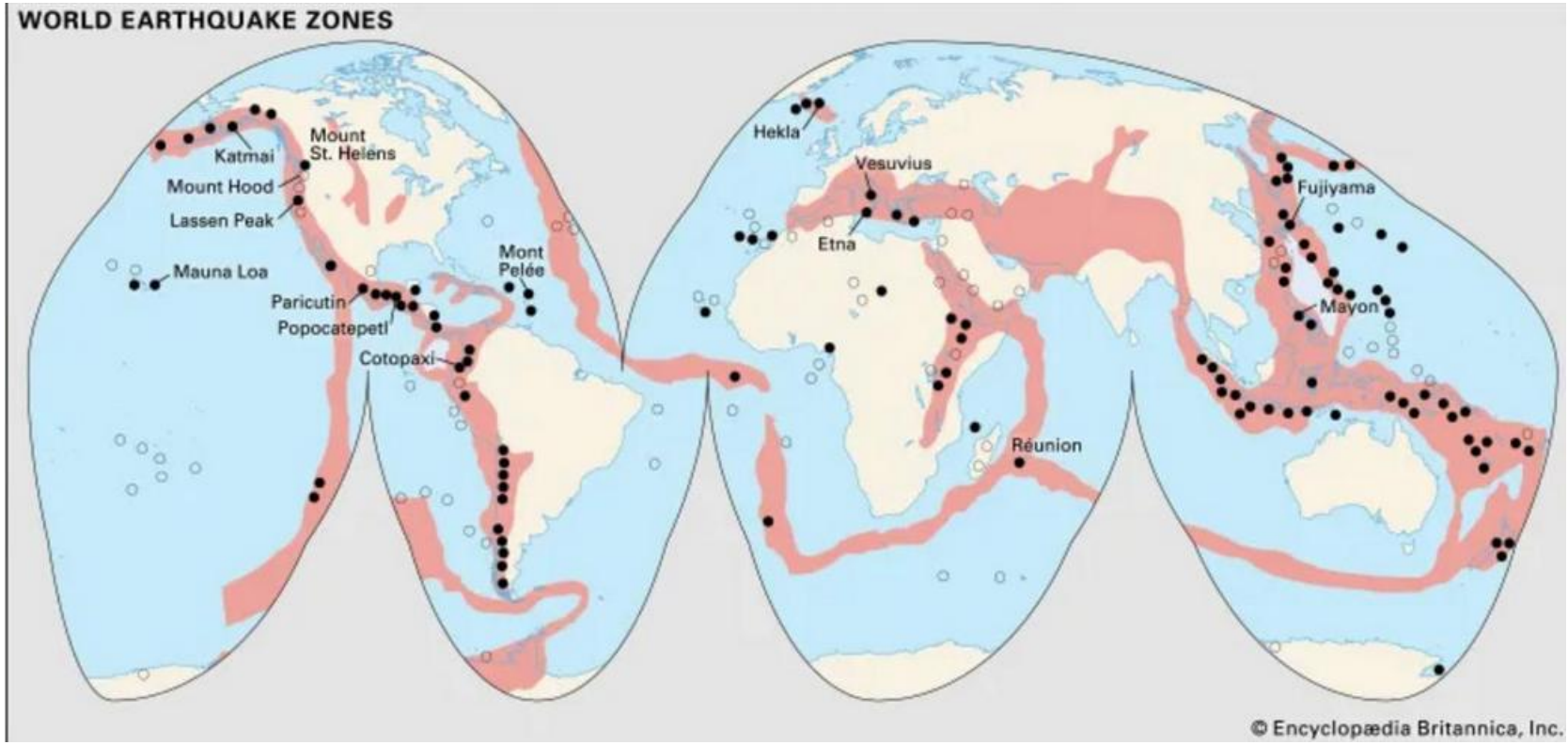
Human causalities

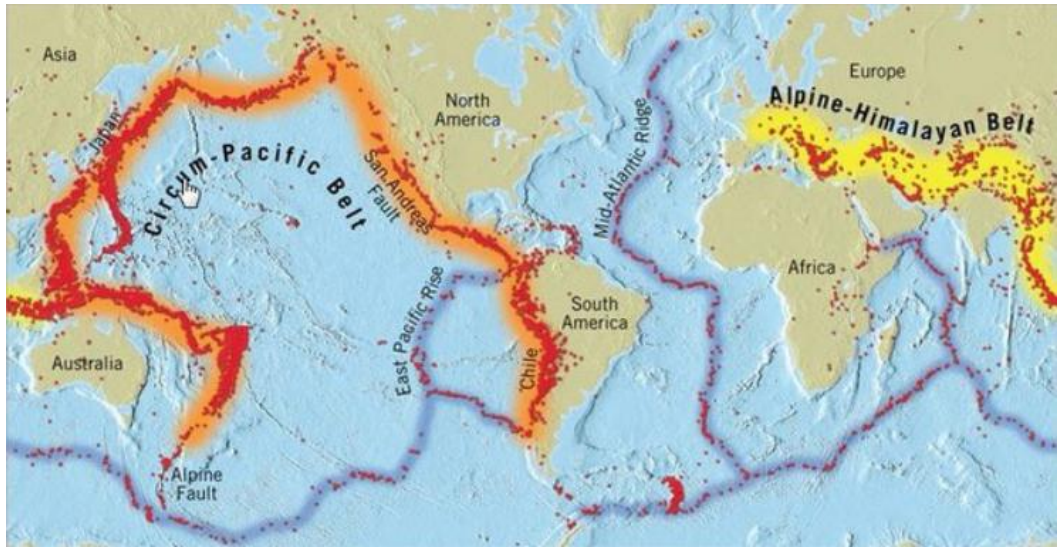
1. Moderate (deaths<50,oo)
2. Highly hazardous(51,000-1,00,00)
3. Most hazardous(>1,00,00)



Distribution of Earthquake

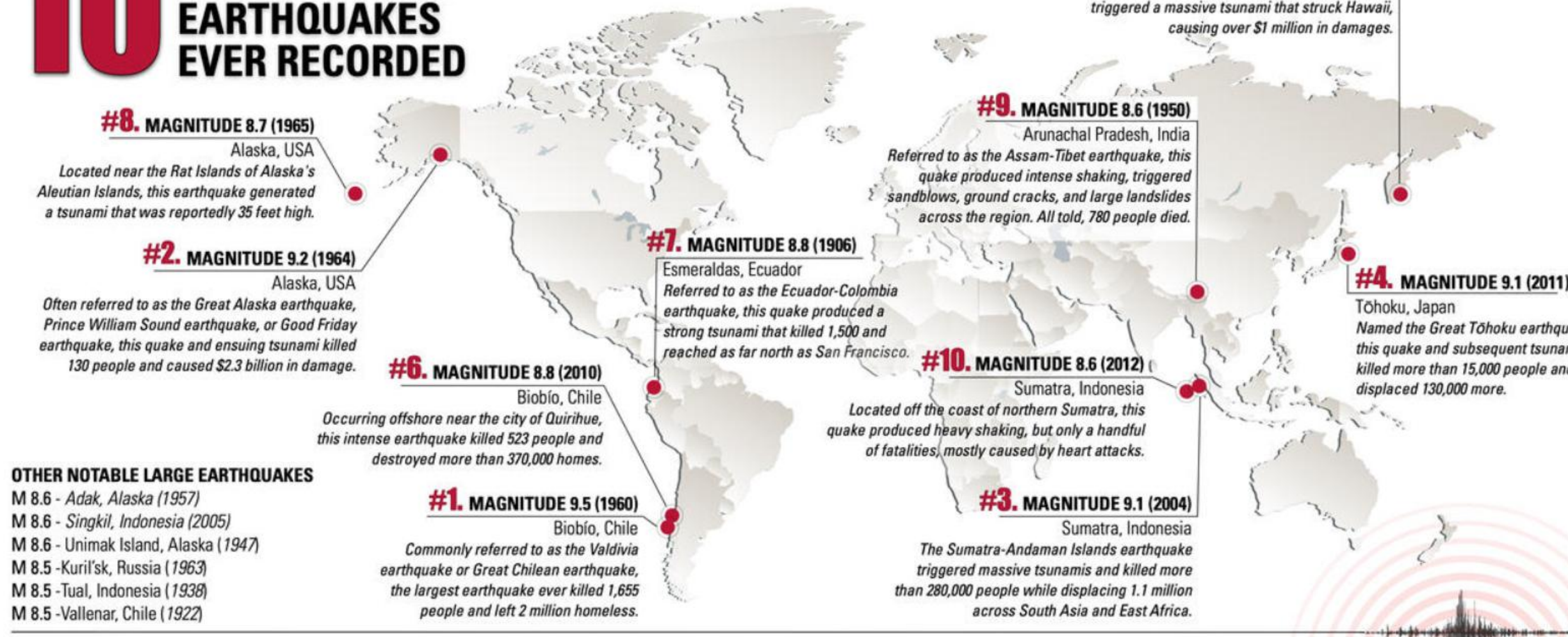



WORLD EARTHQUAKE ZONES
Katmai
Mount St. Helens
Mount Hood
Lassen Peak
Mauna Loa
Paricutin
Popocatepetl
Cotopaxi
Mont Pelée
Hekla
Vesuvius
Etna
Réunion
Fujiyama
Mayon
© Encyclopædia Britannica, Inc.


Asia
Japan
Circum-Pacific Belt
San Andreas Fault
North America
Mid-Atlantic Ridge
Europe
Alpine-Himalayan Belt
Africa
South America
East Pacific Rise
Chile
Australia
Alpine Fault

- Earth's major earthquakes occur mainly in belts coinciding with the margins of tectonic plates.
- The most important earthquake belt is the **Circum-Pacific Belt**, which affects many populated coastal regions around the Pacific Ocean—for example, those of New Zealand, New Guinea, Japan, the Aleutian Islands, Alaska, and the western coasts of North and South America.
- The seismic activity is by no means uniform throughout the belt, and there are many branches at various points.
- Because at many places the Circum-Pacific Belt is associated with volcanic activity, it has been popularly dubbed the "Pacific Ring of Fire."
- **The Pacific Ring of Fire accounts for about 68 per cent of all earthquakes.**
- A second belt, known as the **Alpine Belt (Himalayas and Alps)**. The energy released in earthquakes from this belt is about 15 per cent of the world total.
- The mid-world mountain belt (Alpine Belt) extends parallel to the equator from Mexico across the Atlantic Ocean, the Mediterranean Sea from Alpine-Caucasus ranges to the Caspian, Himalayan mountains and the adjoining lands.
- There also are striking connected belts of seismic activity, mainly along oceanic ridges—including those in the Arctic Ocean, the Atlantic Ocean, and the western Indian Ocean—and along the **rift valleys of East Africa**.

10 LARGEST EARTHQUAKES EVER RECORDED



#8. MAGNITUDE 8.7 (1965)
Alaska, USA
Located near the Rat Islands of Alaska's Aleutian Islands, this earthquake generated a tsunami that was reportedly 35 feet high.

#2. MAGNITUDE 9.2 (1964)
Alaska, USA
Often referred to as the Great Alaska earthquake, Prince William Sound earthquake, or Good Friday earthquake, this quake and ensuing tsunami killed 130 people and caused $2.3 billion in damage.

#6. MAGNITUDE 8.8 (2010)
Biobío, Chile
Occurring offshore near the city of Quirihue, this intense earthquake killed 523 people and destroyed more than 370,000 homes.

#1. MAGNITUDE 9.5 (1960)
Biobío, Chile
Commonly referred to as the Valdivia earthquake or Great Chilean earthquake, the largest earthquake ever killed 1,655 people and left 2 million homeless.

#7. MAGNITUDE 8.8 (1906)
Esmeraldas, Ecuador
Referred to as the Ecuador-Colombia earthquake, this quake produced a strong tsunami that killed 1,500 and reached as far north as San Francisco.

#5. MAGNITUDE 9.0 (1952)
Kamchatka Krai, Russia
The world's first recorded magnitude 9 earthquake triggered a massive tsunami that struck Hawaii, causing over $1 million in damages.

#9. MAGNITUDE 8.6 (1950)
Arunachal Pradesh, India
Referred to as the Assam-Tibet earthquake, this quake produced intense shaking, triggered sandblows, ground cracks, and large landslides across the region. All told, 780 people died.

#4. MAGNITUDE 9.1 (2011)
Tōhoku, Japan
Named the Great Tōhoku earthquake, this quake and subsequent tsunami killed more than 15,000 people and displaced 130,000 more.

#10. MAGNITUDE 8.6 (2012)
Sumatra, Indonesia
Located off the coast of northern Sumatra, this quake produced heavy shaking, but only a handful of fatalities, mostly caused by heart attacks.

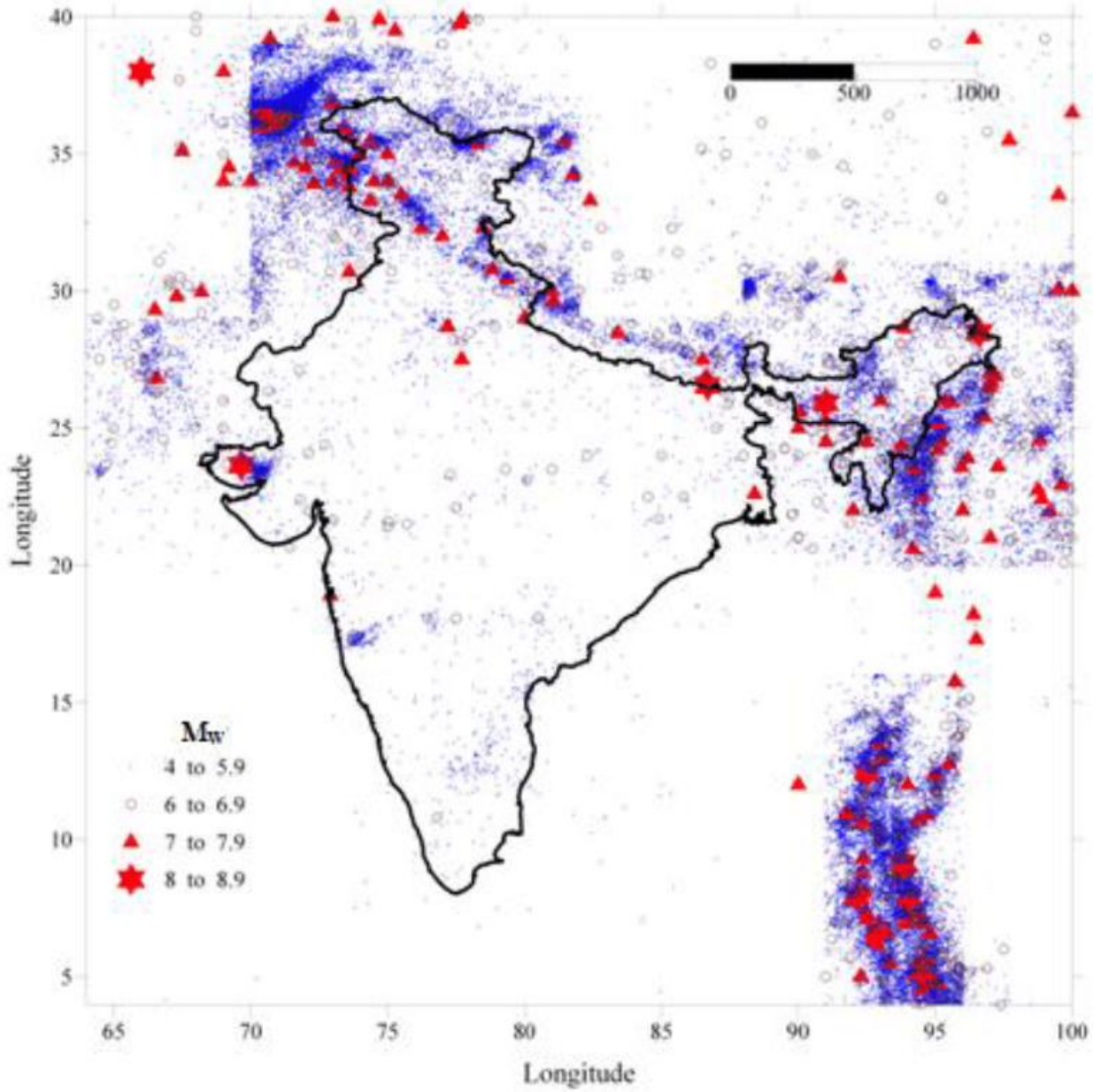
#3. MAGNITUDE 9.1 (2004)
Sumatra, Indonesia
The Sumatra-Andaman Islands earthquake triggered massive tsunamis and killed more than 280,000 people while displacing 1.1 million across South Asia and East Africa.

OTHER NOTABLE LARGE EARTHQUAKES

M 8.6 - *Adak, Alaska (1957)*
M 8.6 - *Singkil, Indonesia (2005)*
M 8.6 - Unimak Island, Alaska (*1947*)
M 8.5 -Kuril'sk, Russia (*1963*)
M 8.5 -Tual, Indonesia (*1938*)
M 8.5 -Vallenar, Chile (*1922*)

USGS science for a changing world

U.S. Department of the Interior
U.S. Geological Survey



#	Year of Occurrence	Location/Affected Areas	Magnitude	Deaths
1	2015 (April 25)	Nepal/Bihar, West Bengal, Uttar Pradesh, Delhi	7.9	79 (India)
2	2011 (Sep. 18)	Gangtok, Sikkim	6.9	7,860
3	2005 (October 8)	Kashmir	7.6	1309
4	2004 (Dec. 26)	Sumatara/ Coastal areas of Tamil Nadu, Andhra Pradesh and Kerala	9.3	16,389
5	2001 (January 26)	Kutch, Gujarat	7.7	20,005
6	1999 (March 29)	Chamoli, Uttarakhand	6.8	100
7	1997 (May 22)	Jabalpur, Madhya Pradesh	6.0	56
8	1993 (Sep. 30)	Latur, Maharashtra	6.3	9,748
9	1991(October 20)	Uttarkashi ,Uttarakhand	6.6	2,000
10	1988 (August 21)	Bihar-Nepal Border	6.4	382
11	1975 (January 19)	Himachal Pradesh	6.2	47
12	1950 (August 15)	Arunachal Pradesh	8.5	1500
13	1934 (January, 15)	Bihar	8.3	6000
14	1905 (April 4)	Kangra, Himachal Pradesh	8.0	20,000

Source: Compiled from GoI 2011, EM-DAT (www.emdat.be); IMD (www.imd.gov.in)

Negative

1. **Huge loss of life and property**. [Most damage is near the epicentre] Earthquake of 7.9 magnitude (Richter scale) on 26 January 2001 in Bhuj, Gujarat.
2. **Infrastructural damage**, such as houses, dams etc. break down.
3. Blockage in the path of rivers due to earthquakes, causing floods in nearby areas. Flood in Brahmaputra and its tributaries due to Assam earthquake in 1950.
4. Problem of floods due to breaking of dams etc.
5. Earthquakes in sea areas cause huge waves [**tsunami**] which cause heavy damage in coastal areas.
6. Landslides in mountainous areas.
7. Earthquakes cause **formation of huge faults** on the earth's surface, which affects traffic, for example – Japan earthquake in 1891, California earthquake in 1906.
8. Earthquakes can cause fires by damaging power supply lines or gas pipelines. The 1906 San Francisco earthquake caused more deaths from fires than from the earthquake itself.

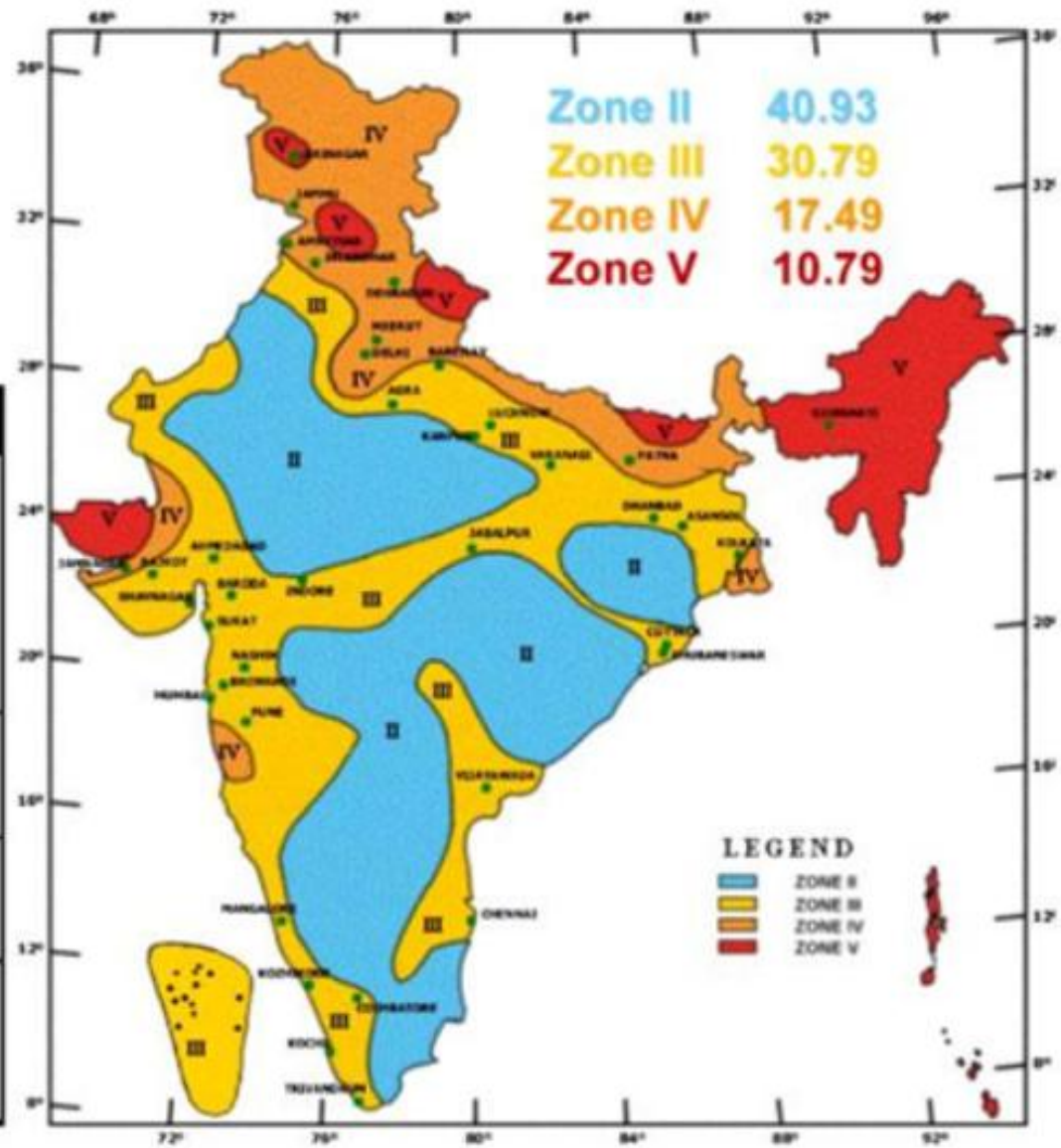
Positives

1. Formation of new islands or plains due to the rise of submerged land in sea areas.
2. Formation of new topographies (like mountains, plateaus, valleys etc.) due to folding or faulting caused by earthquakes.
3. Helpful in understanding the internal structure of the earth.
4. Earthquakes cause large cracks on the earth's surface from which minerals can be obtained.
5. Volcanic eruption caused by earthquakes causes the spread of lava on the surface. This gives black soil which is useful for the cultivation of cotton and wheat.

Seismic Zone Map of India: -2002

About 59 percent of the land area of India is liable to seismic hazard damage

Zone	Intensity
Zone V	Very High Risk Zone Area liable to shaking Intensity IX (and above)
Zone IV	High Risk Zone Intensity VIII
Zone III	Moderate Risk Zone Intensity VII
Zone II	Low Risk Zone VI (and lower)



Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion

Energy that travels trough the earth and is recorded on seismographs and the instrument called **seismogram**.

Seismic waves are defined by:

Where they move – Earths's interior Vs Surface

How they move – Vertically Vs Horizontally

How fast they move – metres per second

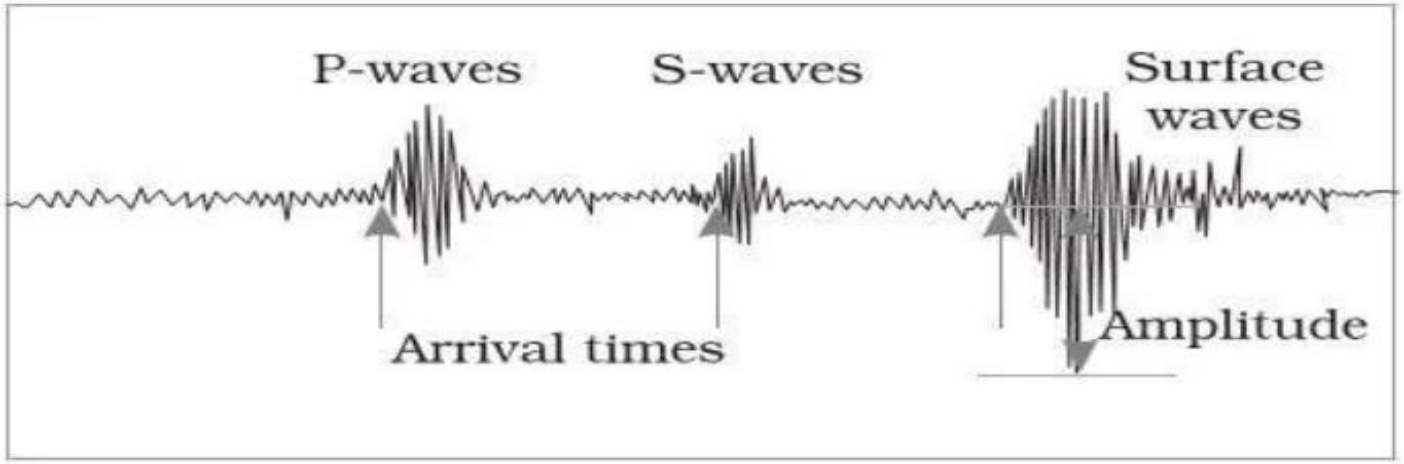
- **The release of energy occurs along a fault.**
- **A fault is a sharp break in the crustal rock layer.**
- **Rocks along a fault tend to move in opposite directions. But the friction exerted by the overlying rock strata prevents the movement of the rock layer, with time pressure builds up.**
- **Under intense pressure, the rock layer, at a certain point, overcomes the friction offered by the overlying layer and undergoes an abrupt movement generating shockwaves.**
- **This causes a release of energy, and the energy waves travel in all directions.**

- **The point where the energy is released is called the s focus of an earthquake, alternatively, it is called the hypocenter.**

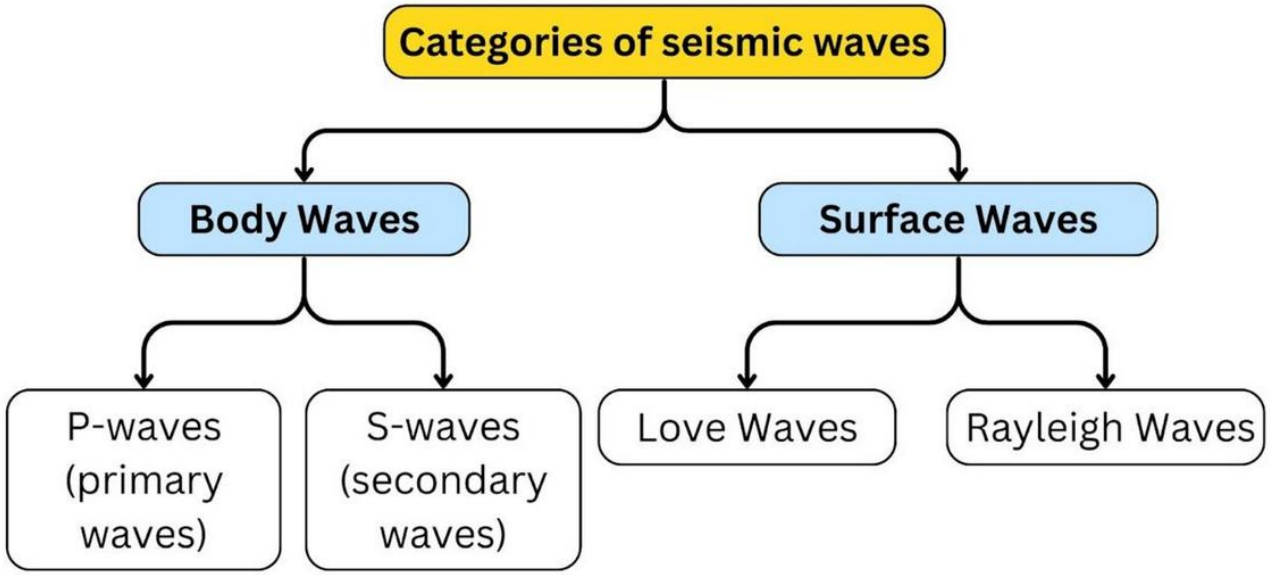
- **The energy waves traveling in different directions reach the surface. The point on the surface, nearest to the focus, is called the epicenter. It is the first one to experience the waves. It is a point directly above the focus.**

Seismic Waves

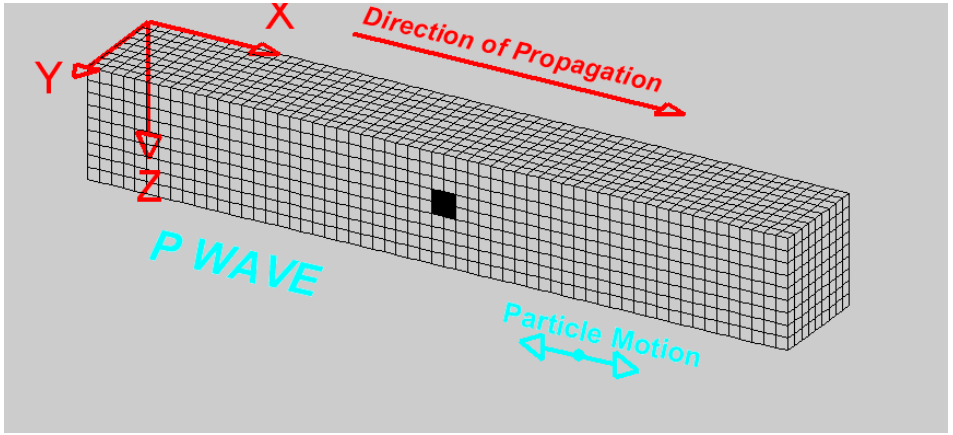
- **The behavior of Earthquake Waves**
- The earthquake waves are measured with the help of a seismograph and are of three types—
  - The ‘P’ waves or primary waves (longitudinal nature)
  - Secondary waves or ‘S’ waves (transverse in nature)
  - Surface waves or ‘L’ waves are long.
- The n velocity and direction of the earthquake waves undergo changes when the medium through which they are traveling changes.
- When an earthquake or underground nuclear test sends shock waves through the Earth, the cooler areas, which generally are rigid, transmit these waves at a higher velocity than the hotter areas.



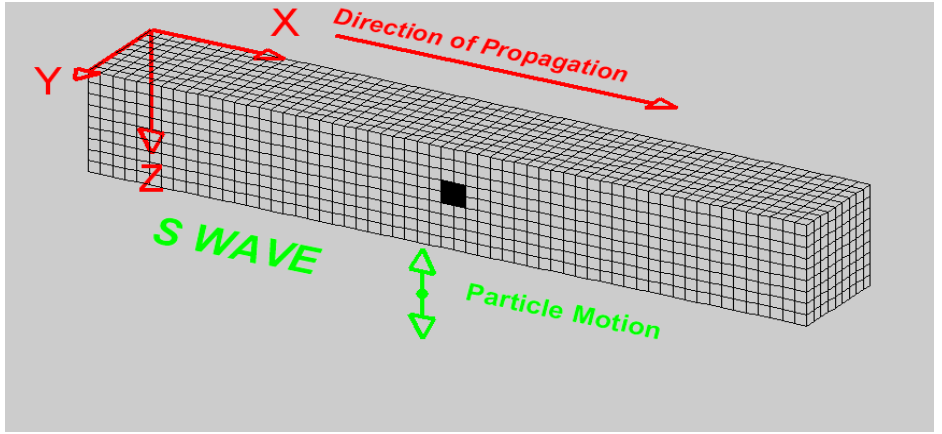
- All-natural earthquakes take place in the lithosphere (depth up to 200 km from the surface of the earth).
- An instrument called '**seismograph**' records the waves reaching the surface.
- Earthquake waves are basically of two types **– body waves** and **surface waves.**
- Body waves are generated due to the release of energy at the focus and move in all directions traveling through the body of the earth. Hence, the name body waves.
- The body waves interact with the surface rocks and generate a new set of waves called surface waves. These waves move along the surface.



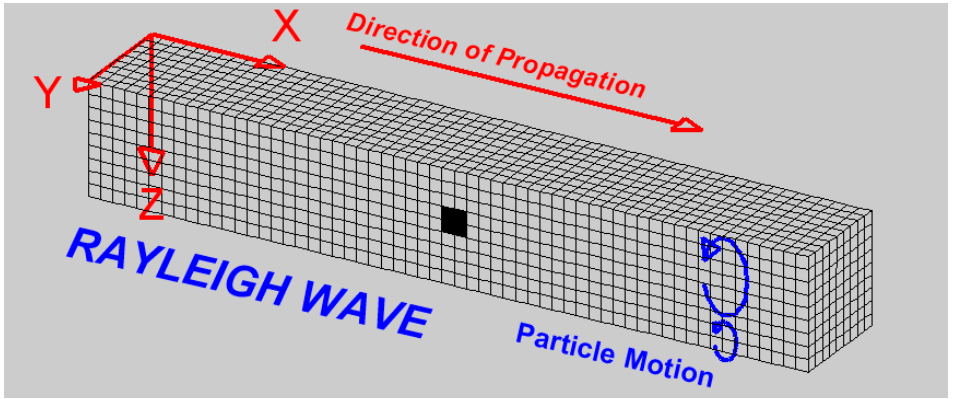
Four Types of Seismic Waves (http://web.ics.purdue.edu/~braile/new/SeismicWaves4Types.ppt)



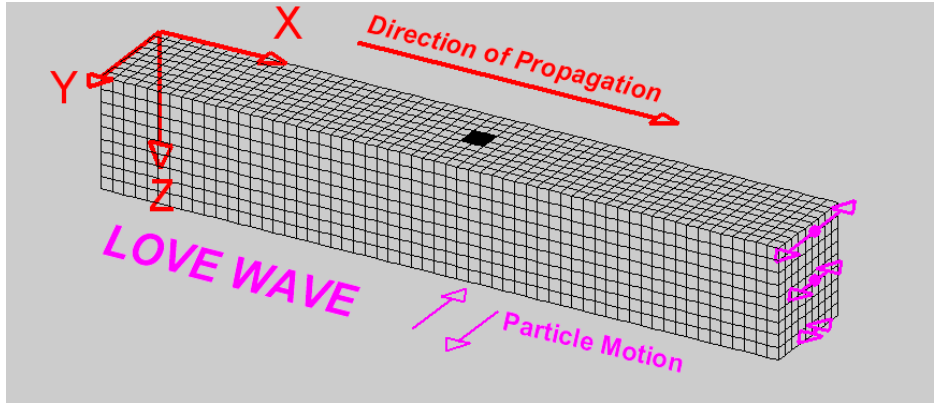
Deformation propagates. Particle motion consists of alternating compression and dilation. Particle motion is parallel to the direction of propagation (longitudinal). Material returns to its original shape after wave passes.



Deformation propagates. Particle motion consists of alternating transverse motion, perpendicular to direction of propagation. Transverse motion can be in any direction. Material returns to its original shape after wave passes.

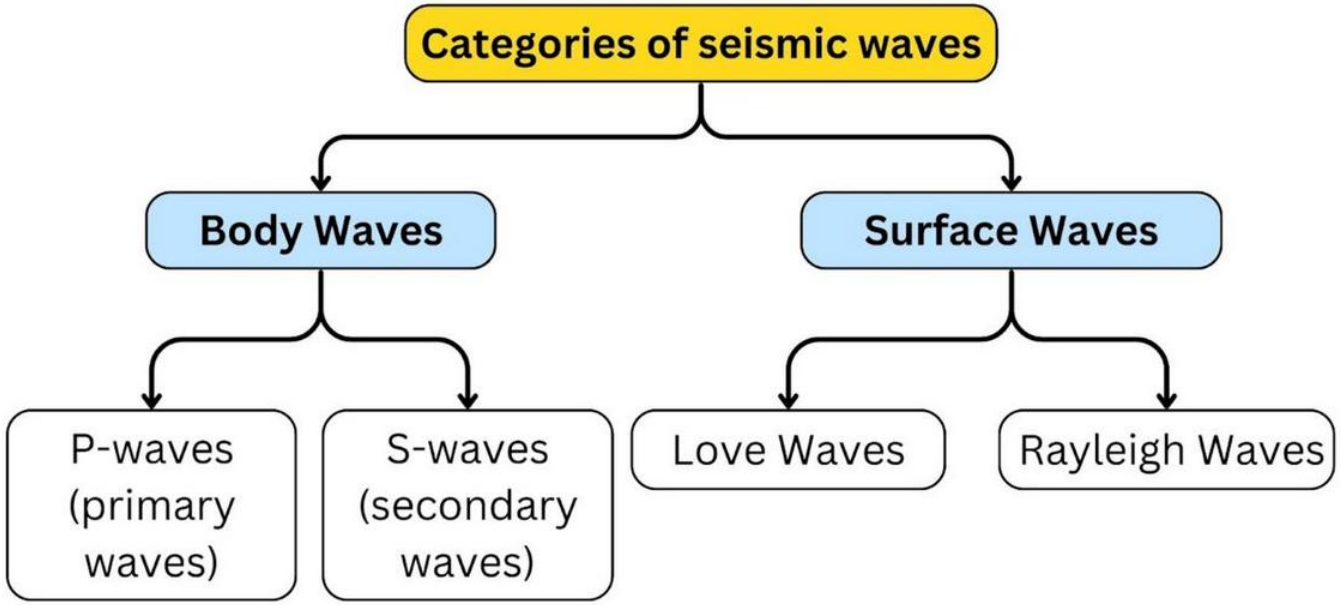


Deformation propagates. Particle motion consists of elliptical motions (generally retrograde elliptical) in the vertical plane and parallel to the direction of propagation. Amplitude decreases with depth. Material returns to its original shape after wave passes.



Deformation propagates. Particle motion consists of alternating transverse motions. Particle motion is horizontal and perpendicular to the direction of propagation (transverse). Amplitude decreases with depth. Material returns to its original shape after wave passes.

- The velocity of waves changes as they travel through materials with different elasticity (stiffness) (Generally density with few exceptions). The more elastic the material is, the higher is the velocity. Their direction also changes as they reflect or refract when coming across materials with different densities.
- There are two types of body waves.
- They are called P and S-waves.
- There are two types of body waves
- L, Love, Surface waves, Long waves & R, Rayleigh, Surface waves, Long waves,

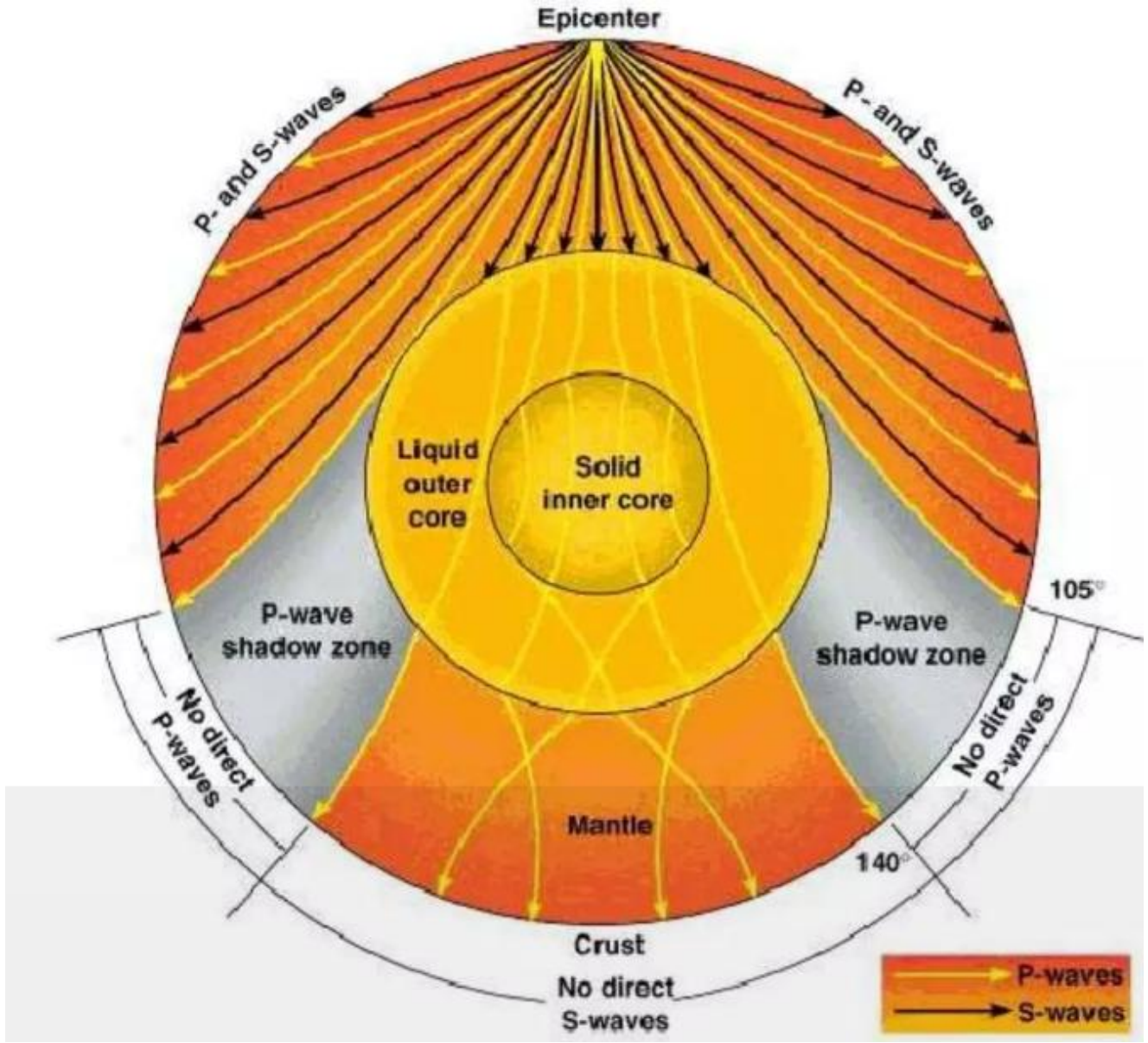


Primary Waves (P waves)

- Also called the longitudinal or compressional waves.
- Particles of the medium vibrate along the direction of propagation of the wave.
- P-waves move faster and are the first to arrive at the surface.
- These waves are of high frequency.
- They can travel in all mediums.
- The velocity of P waves in Solids > Liquids > Gases
- Their velocity depends on y shear strength or elasticity of the material.
- The shadow zone for ‘P’ waves is an area that corresponds to an angle between 103° and 142°.
- This gives clues about the Solid inner core.

Secondary Waves (S waves)

- Also called as transverse or distortion waves.
- Analogous to water ripples or light waves.
- S-waves arrive at the surface with some time lag.
- A secondary wave cannot pass through liquids or gases.
- These waves are of high-frequency waves.
- Travel at varying velocities (proportional to shear strength) through the solid part of the Earth's crust, mantle.
- The shadow zone of 'S' waves extends y almost halfway around the globe from the earthquake's focus.
- The shadow zone for 'S' waves is an area that corresponds to an angle between 103° and 103°.
- This observation led to the discovery of the liquid outer core. Since S waves cannot travel through liquid, they do not pass through the liquid outer core.


Epicenter
P- and S-waves
P- and S-waves
Liquid outer core
Solid inner core
P-wave shadow zone
P-wave shadow zone
105°
No direct P-waves
No direct P-waves
Mantle
140°
Crust
No direct S-waves
P-waves
S-waves

Surface Waves (L waves)

- Also called long-period waves.
- They are low frequency, long wavelength, and transverse vibration.
- Generally, they affect the surface of the Earth only and die out at a smaller depth.
- Develop in the immediate neighborhood of the epicenter.
- They cause displacement of rocks, and hence, the collapse of structures occurs.
- These waves are responsible for most of the destructive force of the earthquake.
- Recorded last on the seismograph.

Propagation of Earthquake Waves

- Different types of earthquake waves travel in different manners. As they move or propagate, they cause vibration in the body of the rocks through which they pass.
- P-waves vibrate parallel to the direction of the wave. This exerts pressure on the material in the direction of the propagation.
- As a result, it creates density differences in the material leading to stretching and squeezing of the material.
- The other two waves vibrate perpendicular to the direction of propagation.
- The direction of vibrations of S-waves is perpendicular to the wave direction in the vertical plane. Hence, they create s troughs and crests in the material through which they pass.

Characteristics of Seismic Waves

Seismic Waves			
Type (and names)	**Particle Motion**	**Typical Velocity**	**Other Characteristics**
P,Compressional, Primary, Longitudinal	Alternating compressions ("pushes") and dilations ("pulls") which are directed in the same direction as the wave is propagating (along the raypath); and therefore, perpendicular to the wavefront	$V_P \sim 5 - 7$ km/s in typical Earth's crust; $\gtrsim 8$ km/s in Earth's mantle and core; 1.5 km/s in water; 0.3 km/s in air	P motion travels fastest in materials, so the P-wave is the first-arriving energy on a seismogram. Generally smaller and higher frequency than the S and Surface-waves. P waves in a liquid or gas are pressure waves, including sound waves.
S, Shear, Secondary, Transverse	Alternating transverse motions (perpendicular to the direction of propagation, and the raypath); commonly polarized such that particle motion is in vertical or horizontal planes	$V_S \sim 3 - 4$ km/s in typical Earth's crust; $\gtrsim 4.5$ km/s in Earth's mantle; ~ 2.5-3.0 km/s in (solid) inner core	S-waves do not travel through fluids, so do not exist in Earth's outer core (inferred to be primarily liquid iron) or in air or water or molten rock (magma). S waves travel slower than P waves in a solid and, therefore, arrive after the P wave.

Type (and names)	Particle Motion	Typical Velocity	Characteristics
L, Love, Surface waves, Long waves	Transverse horizontal motion, perpendicular to the direction of propagation and generally parallel to the Earth's surface	$V_L \sim$ 2.0 - 4.5 km/s in the Earth depending on frequency of the propagating wave	Love waves exist because of the Earth's surface. They are largest at the surface and decrease in amplitude with depth. Love waves are dispersive, that is, the wave velocity is dependent on frequency, with low frequencies normally propagating at higher velocity. Depth of penetration of the Love waves is also dependent on frequency, with lower frequencies penetrating to greater depth.
R, Rayleigh, Surface waves, Long waves, Ground roll	Motion is both in the direction of propagation and perpendicular (in a vertical plane), and "phased" so that the motion is generally elliptical – either prograde or retrograde	$V_R \sim$ 2.0 - 4.5 km/s in the Earth depending on frequency of the propagating wave	Rayleigh waves are also dispersive and the amplitudes generally decrease with depth in the Earth. Appearance and particle motion are similar to water waves.

Thank You