ENVIRONMENTAL GEOLOGY

Earthquakes

Dr. Hazim Jumaa

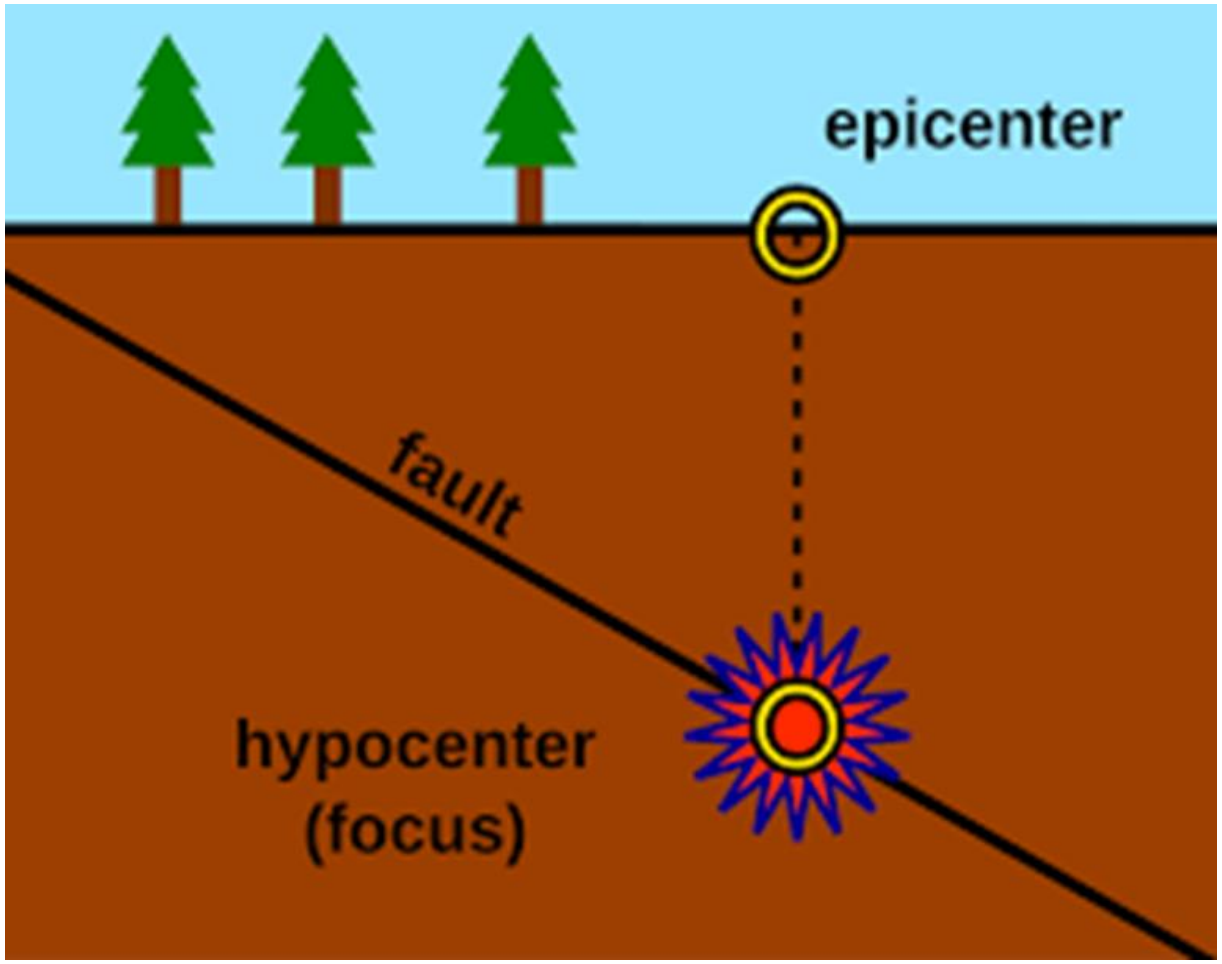
Earthquakes

Earthquakes are vibrational movements that occur due to shifts in the lithosphere, sometimes reaching depths of hundreds of kilometers. These natural phenomena are recorded worldwide, with global observatories detecting approximately one million earthquakes each year.

A powerful earthquake can lead to severe economic and human losses, with the energy released being comparable to that of 100,000 atomic bombs. Consequently, seismic engineering techniques have been developed, and specialized standards for earthquake-resistant structures have been implemented.

Earthquake Mechanism

An earthquake originates at a focal point beneath the surface, known as the focus. Seismic waves generated at this point travel through the Earth's crust, causing surface vibrations. The epicentre**r is the location on the Earth's surface directly above the focus.** While most earthquakes last only a few seconds, severe ones can persist for several minutes.



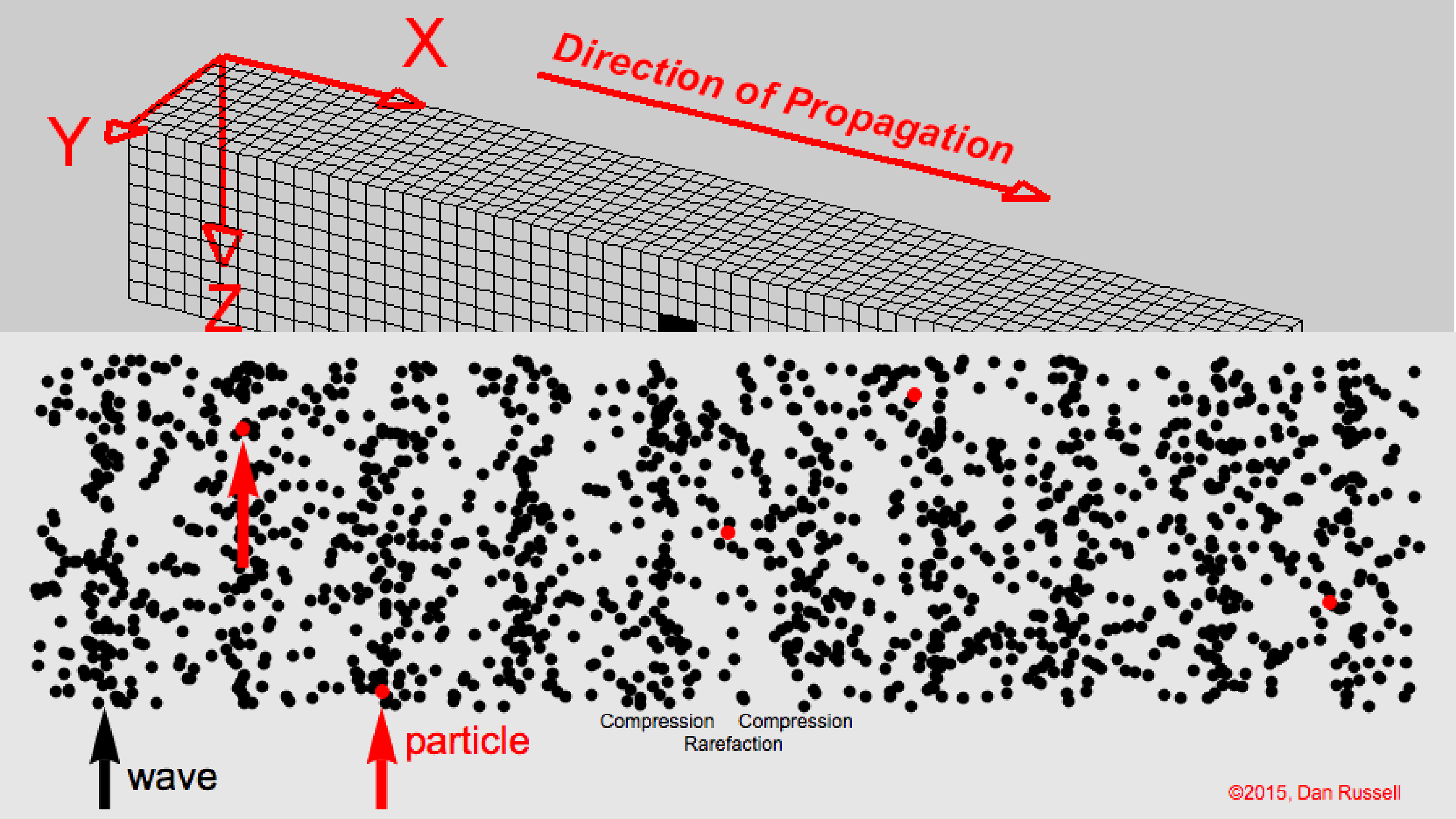
Seismic Waves

Seismic waves propagate in all directions from the earthquake's origin. Some waves travel along the surface, causing destructive shaking, while others penetrate deeper into the Earth, following various paths before resurfacing at distant locations. These waves are classified into two main types:

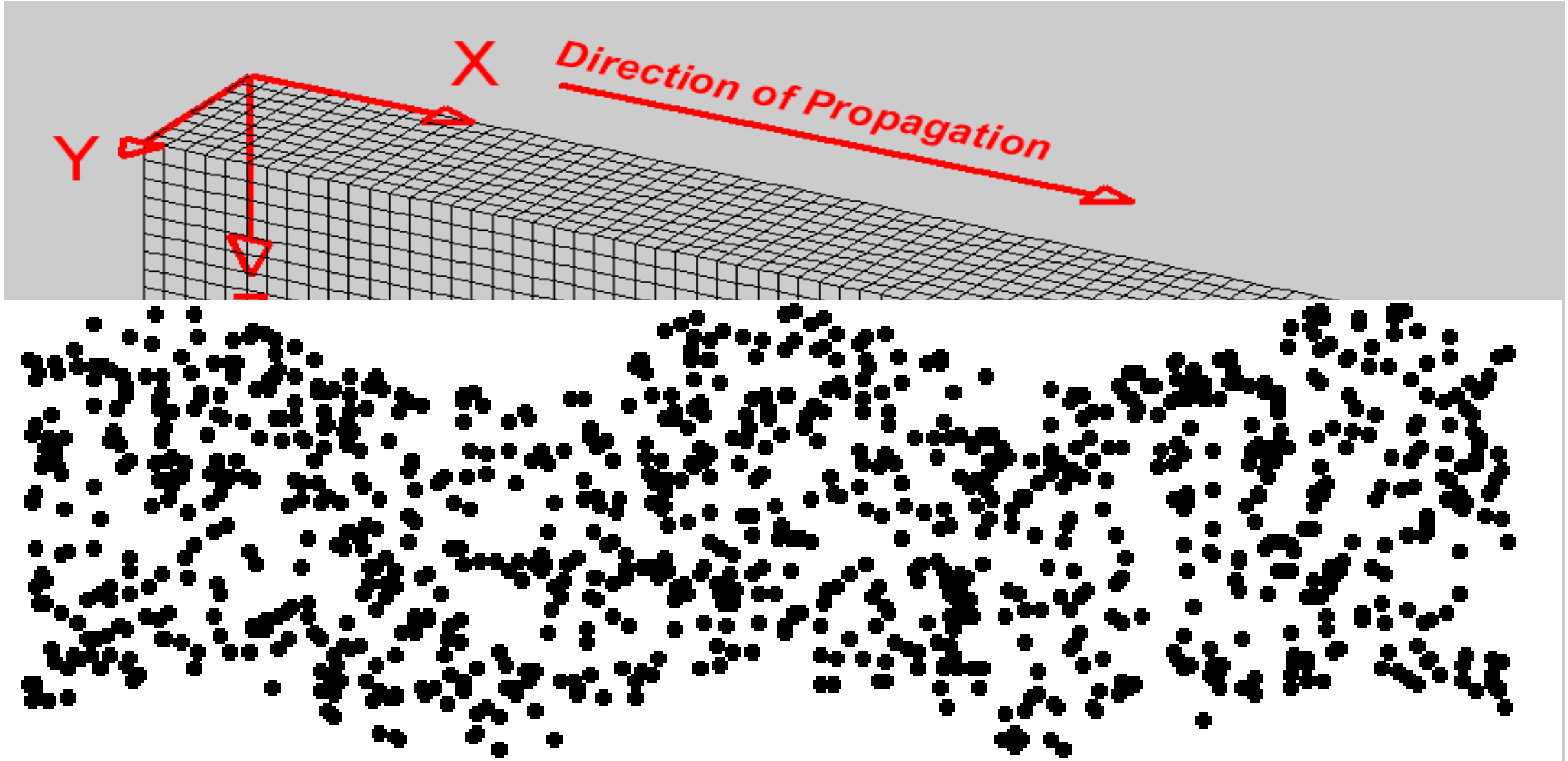
1. Body Waves

These waves move through the Earth's interior and are further divided into:

- **Primary (P) Waves**: Also called longitudinal or pressure waves, these are the fastest seismic waves and the first to be recorded by seismographs. Their speed and clarity make them essential for seismic studies.



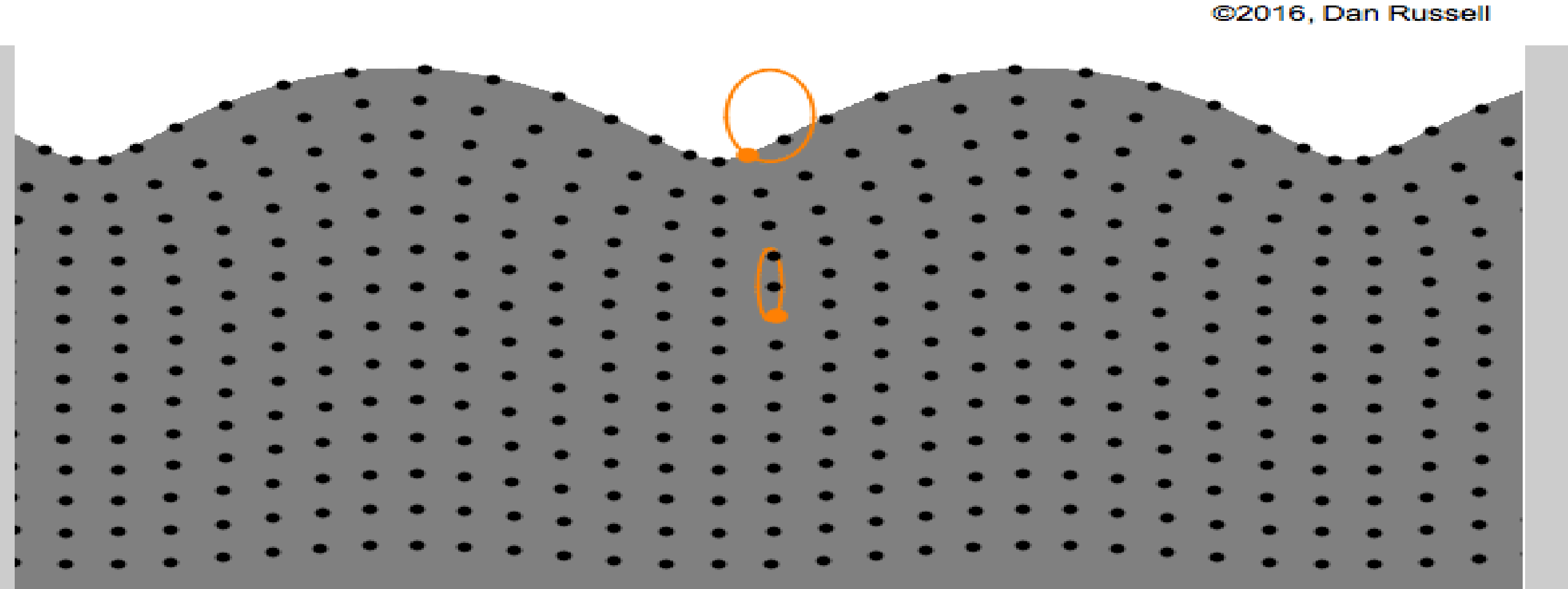
Secondary (S) Waves: Also known as transverse or shear waves, these waves move slower than P waves and oscillate perpendicular to their direction of propagation. Unlike P waves, they do not travel through liquids.



2. Surface Waves

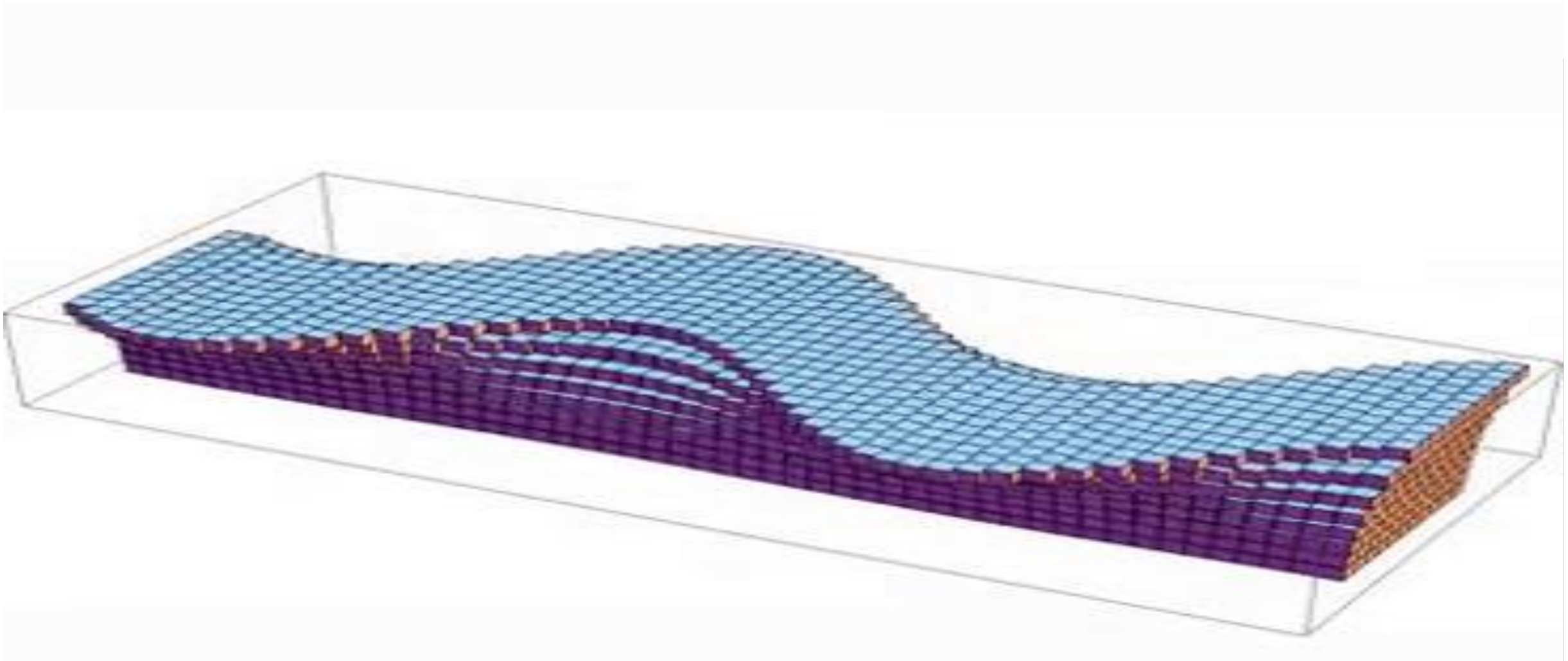
Surface waves travel along the Earth's upper crust and are slower but more destructive than body waves. The two main types are:

- **Rayleigh Waves**

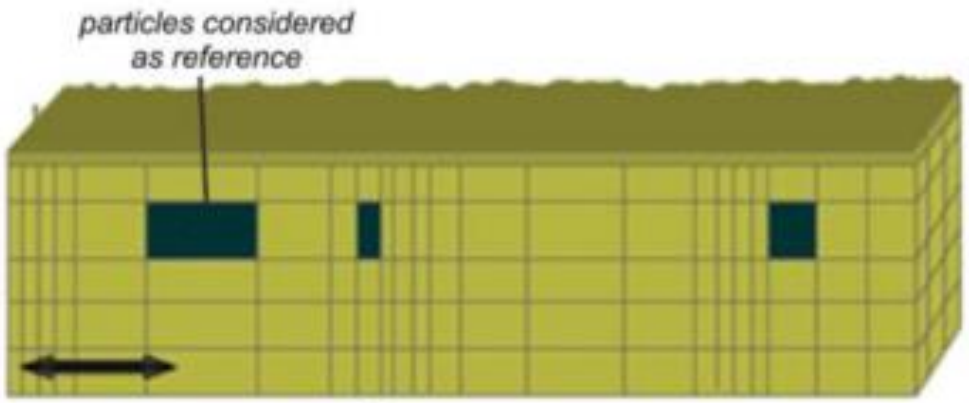


. **Love Waves**

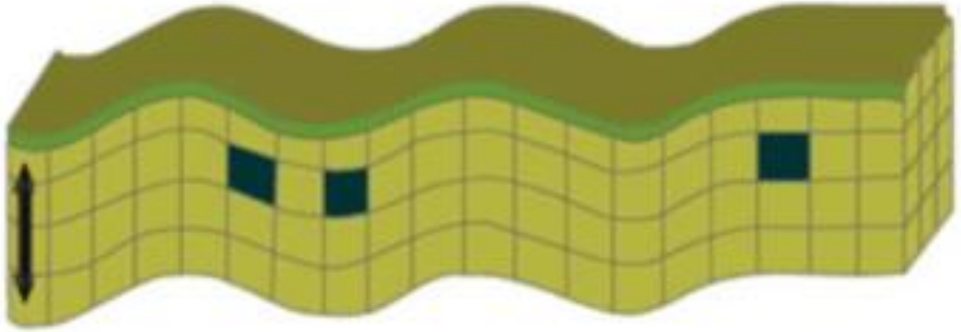
Despite their lower velocity, surface waves—particularly Love waves—are the primary cause of building collapses during earthquakes.



Deep waves



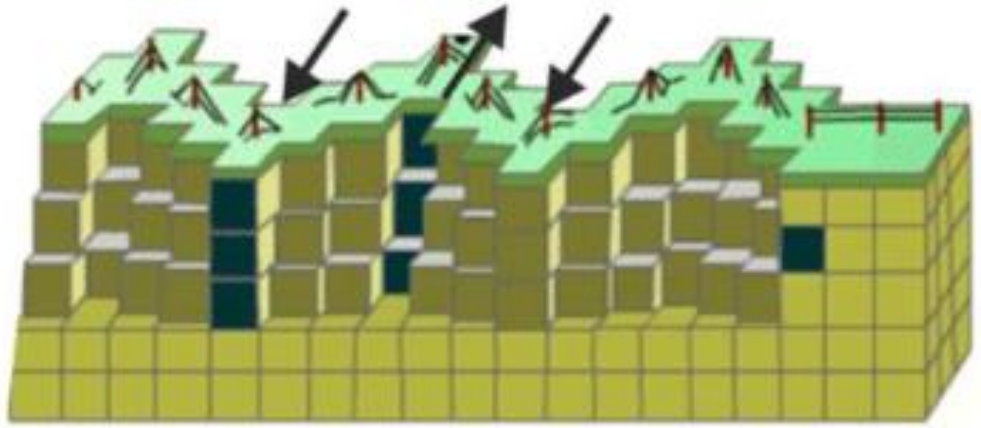
P waves



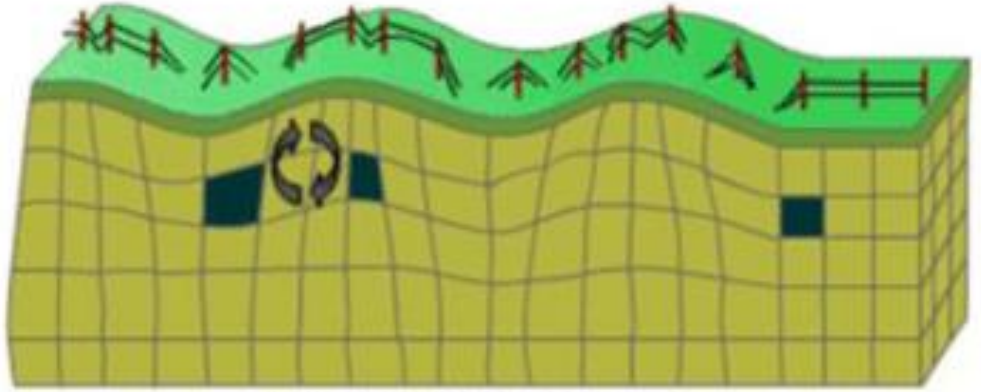
S waves

Direction of wave propagation

Surface waves



Love waves



Rayleigh waves

Direction of wave propagation

Causes of Earthquakes

1. Human-Induced Earthquakes

Certain human activities, such as underground construction, reservoir filling, geothermal energy projects, and mining operations, can trigger earthquakes. These are referred to as **induced earthquakes**.

2. Natural Causes

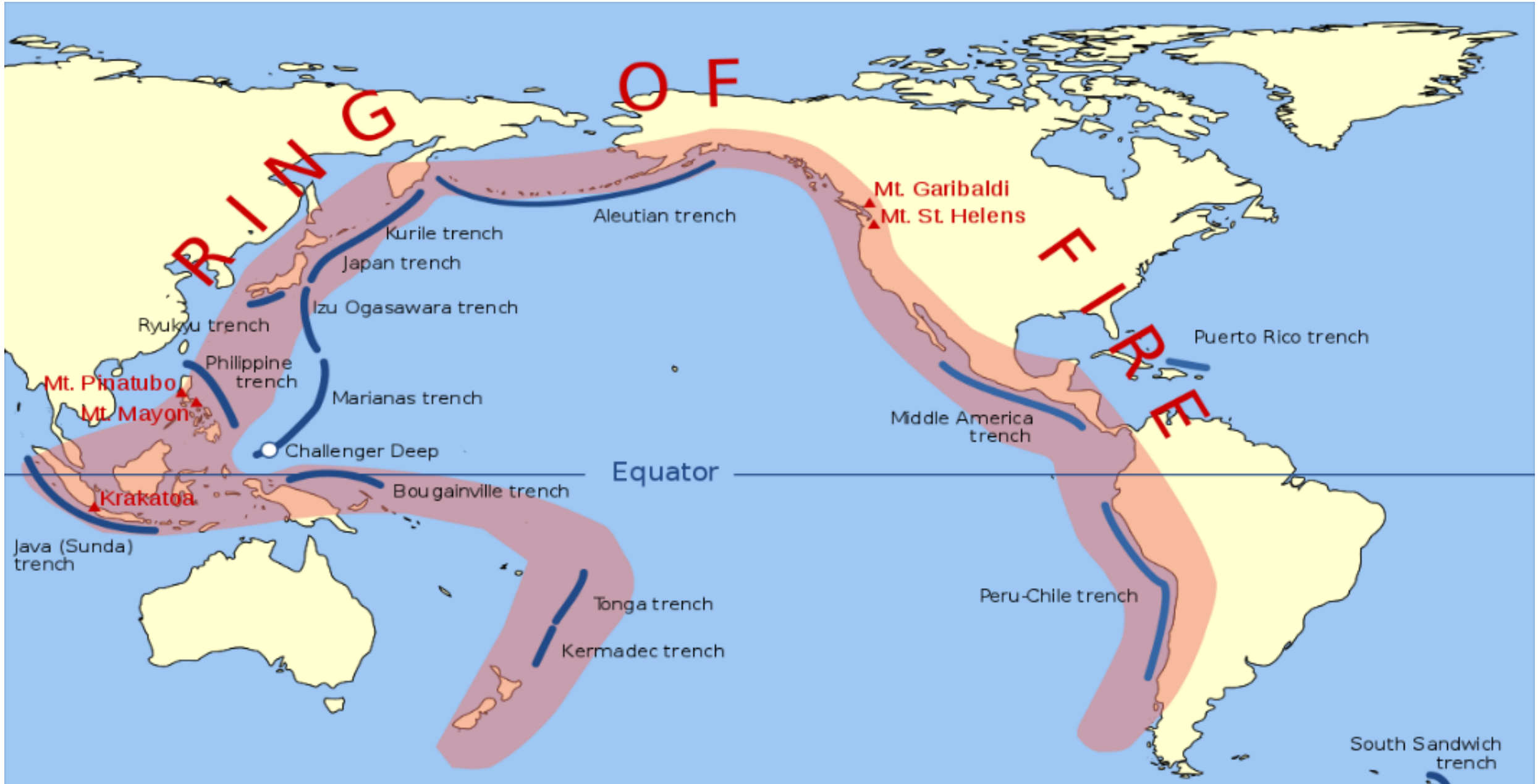
- **Tectonic Earthquakes**: The most common type, is explained by the **plate tectonic theory**, which states that the Earth's crust consists of rigid plates in continuous motion. Their interactions at plate boundaries often result in earthquakes.
- **Volcanic Earthquakes**: These occur due to volcanic activity and are generally weaker than tectonic earthquakes. They are typically felt near the **Focus,** the initial rupture point beneath the surface.

Geographic Distribution of Earthquakes

Seismic activity is concentrated in specific regions known as **seismic belts**, which align with tectonic plate boundaries. The three major earthquake belts are:

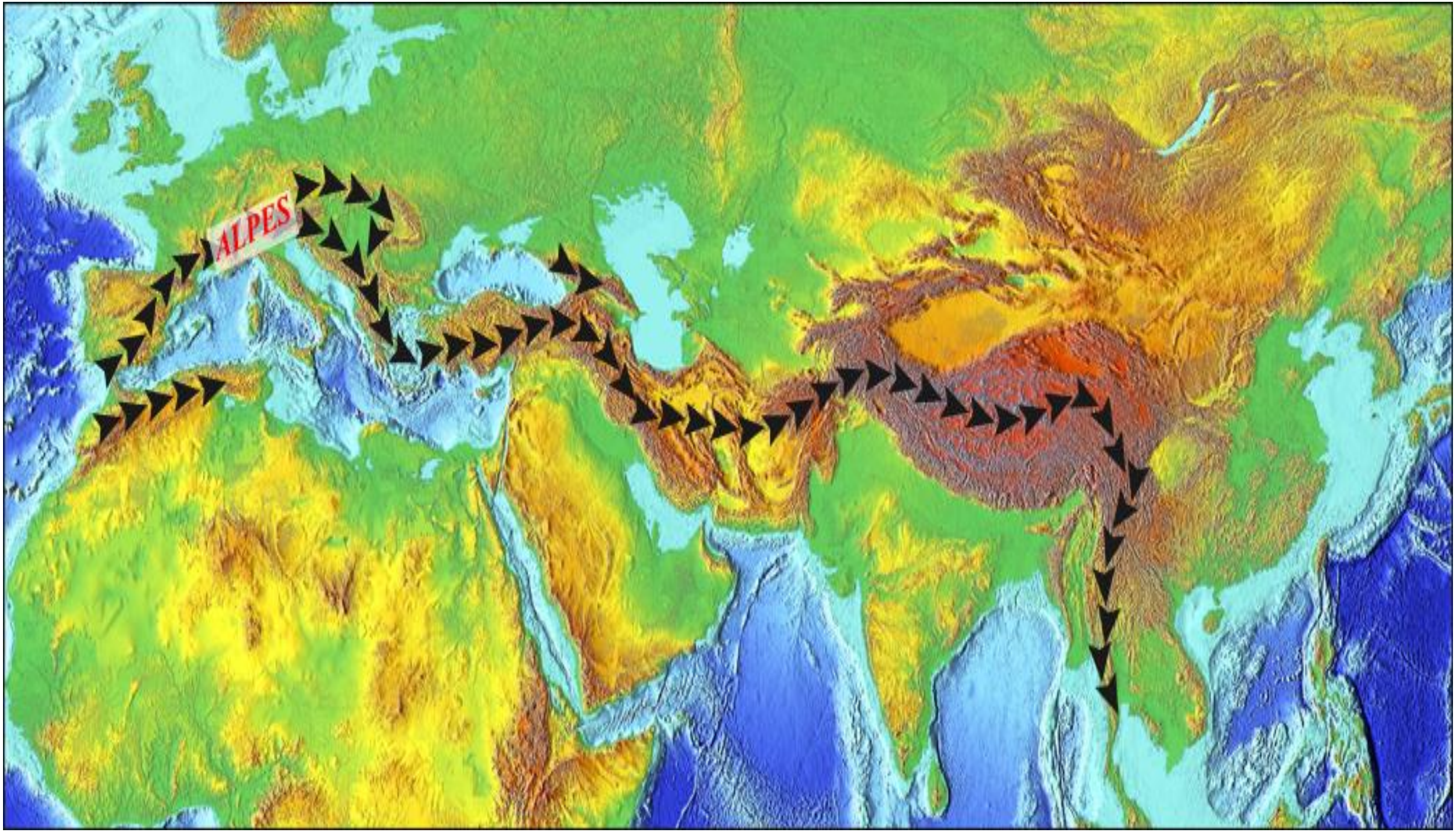
1. The Pacific Belt (Ring of Fire)

This belt, which forms a horseshoe-shaped zone around the Pacific Ocean, is responsible for approximately 90% of the world's earthquakes and includes some of the most violent seismic events, such as the 1960 Chile earthquake (Mw 9.5) and the 1964 Alaska earthquake (Mw 9.1).


RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Ogasawara trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Mt. Pinatubo
Mt. Mayon
Krakatoa
Mt. Garibaldi
Mt. St. Helens
Middle America trench
Puerto Rico trench
Peru-Chile trench
South Sandwich trench
Equator

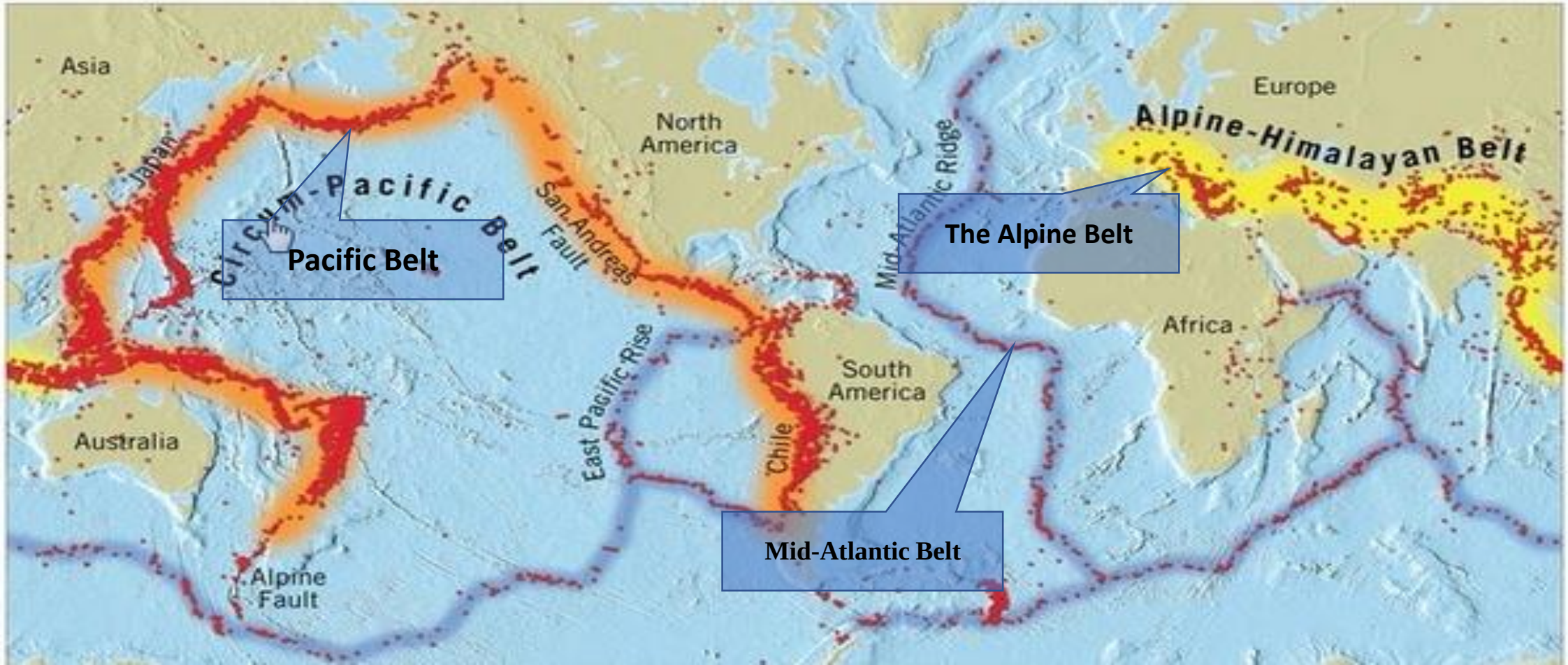
2. The Alpine Belt

Extends from the Atlas Mountains through the Mediterranean, the Alps, the Taurus Mountains, the Zagros Mountains, the Himalayas, and into Southeast Asia, including Indonesia. This belt is responsible for approximately 15-17% of the world's major earthquakes, including the 2005 Pakistan earthquake and the 2004 Sumatra earthquake. It passes through tectonically active regions where the Eurasian Plate collides with the African and Indo-Australian Plates, making it one of the most seismically active belts on Earth.


ALPES

3. The Mid-Atlantic Belt

Situated along the **Mid-Atlantic Ridge**, this belt consists of numerous faults and fractures that generate deep-sea earthquakes. A notable event in this region was a major earthquake in **Iceland**, which sits directly on the tectonic boundary.



Earthquakes are classified based on their depth:

- **Shallow Earthquakes**: Focus depth less than **50 km**.
- **Intermediate-Depth Earthquakes**: Focus depth between **50-250 km**.
- **Deep Earthquakes**: Focus depth between **250-700 km**.

Earthquake Hazards

Earthquakes can cause widespread destruction, including:

Landslides and Avalanches: Seismic shaking can destabilize slopes, leading to rockfalls and soil displacement.

Floods: Earthquakes can damage dams or displace bodies of water, resulting in catastrophic flooding.

Fires: Damage to electrical grids and gas pipelines may lead to uncontrollable fires.

Soil Liquefaction: Water-saturated soil loses its strength, causing buildings and infrastructure to sink or tilt.

Tsunamis: Underwater earthquakes and landslides can trigger massive waves that devastate coastal regions.

Richter Magnitude Scale

Developed in 1935 by Charles F. Richter in collaboration with Beno Gutenberg, the **Richter scale** is a numerical system used to measure earthquake magnitude. It follows a **logarithmic scale**, meaning that each whole number increase represents a **tenfold increase in amplitude** and approximately **32 times more energy release**. The scale ranges from **0 to 10**, with most recorded earthquakes falling below **7**.

Thank You for Listening

Any Questions?