Earthquakes occur when one block of earth slips past another block along surfaces called **faults** or **fault planes** and generates ground shaking.

The area under the earth where the slippage originates is called the **hypocenter** or **focus**. The **epicenter** refers to the point on the Earth's surface that is directly above the hypocenter.

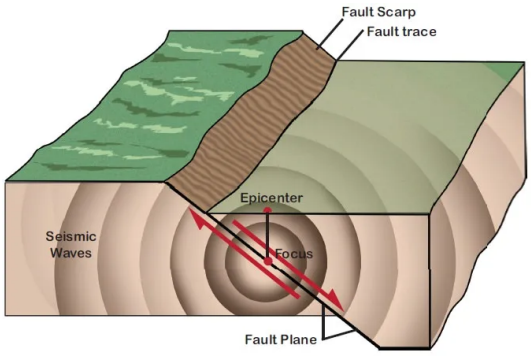


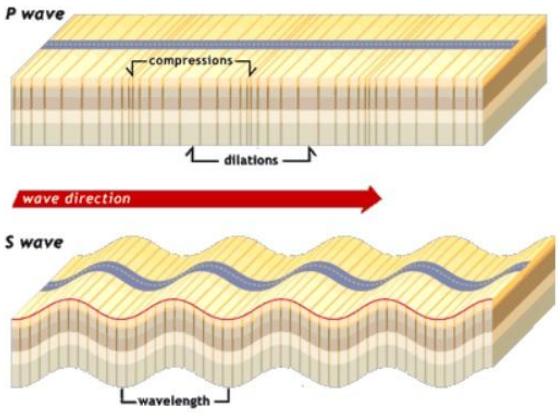
Figure 3.22 Parts of an Earthquake

Seismic Waves.

When slippage happens, the stored energy is released in the form of seismic waves. The seismic waves travel through the earth and cause it to shake. These waves can be classified into two types: **body waves** and **surface waves**.

1. Body waves.

Body waves are waves that travel through the interior of the Earth. There are two types of body waves: **primary waves** (**P waves**) and **secondary waves** or (**S waves**).



Credit: Exploratorium

a. Primary Waves.

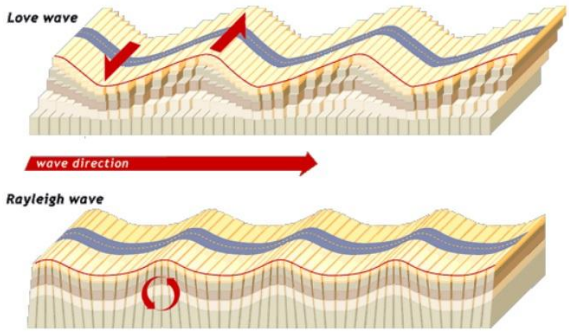
These are the fastest seismic waves and can travel through solid, liquid, and gas. These waves push and pull the rocks in the direction the wave is traveling. They are also called **compressional waves** because of this behavior.

b. Secondary Waves.

These waves cause the rocks to shake up and down at right angles with respect to the direction of the traveling wave. S waves are slower than P waves and can only travel through solids. Because of this, S waves cannot propagate through the liquid outer core. They are also called **shear waves**.

2. Surface waves.

Surface waves, as the name implies, can only travel on the surface of the Earth. These are the waves that can cause tremendous damage. There are also two types:



Credit: Exploratorium

a. Love Waves.

These waves are responsible for shaking the ground horizontally and vertically in an S-like pattern.

b. Rayleigh Waves.

These waves move in a rolling motion similar to ocean waves.

Sometimes, before the main earthquake or **mainshock**, smaller and weaker quakes called **foreshocks** occur. The mainshock is the largest quake in the sequence.

Weaker and shorter quakes called **aftershocks** usually occur afterward. These quakes may or may not be felt, depending on the size of the mainshock, and can even occur over a period of days, weeks, or even months.

Thousands of earthquakes occur every day around the world, but most of these are too small to be felt by people or cause damage.

Seismology.

Seismology is the study of earthquakes. Instruments that are very sensitive to ground shaking called **seismographs** or **seismometers** are used by seismologists to record earthquakes.

In order to describe and classify earthquakes, the intensity and magnitude are determined.

PHIVOLCS Earthquake Intensity Scale (PEIS)

INTENSITY SCALE	SHAKING	DESCRIPTION
1	Scarcely Perceptible	• Water in containers move slowly • Felt by some people
2	Slightly Felt	• Felt by people at rest • Water in containers move noticeably • Hanging objects swing slightly
3	Weak	• Felt by people indoors • Hanging objects swing moderately • Can cause dizziness or nausea in some people
4	Moderately Strong	• Felt by people indoors and outdoors • Hanging objects swing considerably • Objects start to rattle and wood starts to creak • Rumbling sounds can be heard
5	Strong	• Some sleeping people are awakened • Strong shaking and rocking felt indoors • Small, light, and unstable objects may fall and break
6	Very Strong	• Some people lose balance • Heavy objects and furniture move • Old or poorly-built structures may be damaged • Possible rock falls and rolling boulders may occur in hillsides
7	Destructive	• Heavy objects or furniture may topple or overturn • Old or poorly-built structures suffer considerable damage • Liquefaction, lateral spreading, and landslides are observed
8	Very Destructive	• People find it hard to stand even outdoors • Well-built buildings are considerably damaged • Considerable liquefaction and lateral spreading cause damage to property • Numerous landslides and rock falls occur in mountainous or hilly areas • Fissures and fault raptures may be observed
9	Devastating	• People are forcibly thrown to the ground • Most buildings are totally damaged • Bridges and elevated concrete structures destroyed • Widespread liquefaction and landslides • River water splashes violently over dikes and banks
10	Completely Devastating	• Man-made structures are destroyed • Massive landslides and large scale liquefaction and subsidence • Changes in river courses and destructive lake seiches • Many trees are toppled, broken, and uprooted

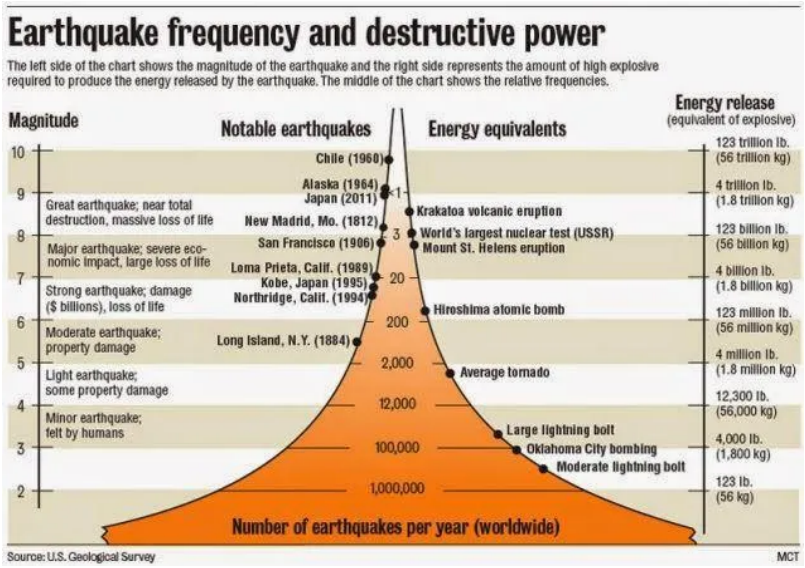
Source: PHIVOLCS

The **intensity** refers to the qualitative measurement of the amount of ground shaking at a certain location, depending on the amount of damage to property, life, and nature.

Different intensity scales are used in different countries. In countries like the United States, the **Modified Mercalli Intensity Scale** is used. In the Philippines, however, the **PHIVOLCS Earthquake Intensity Scale (PEIS)** is used. This scale was developed by the Philippine Institute of Volcanology and Seismology (PHIVOLCS) as a response to the devastating 1990 Luzon Earthquake.

The **magnitude** refers to the quantitative measurement of the amount of energy released at the earthquake's source.

Before, the most commonly used scale for measuring the magnitude is called the **Richter Scale**, which measures the amplitude of the largest seismic wave on a seismogram. Now, seismologists use the **Moment Magnitude (M_w) scale** which measures the total amount of energy released by an earthquake. The Moment Magnitude scale proves to be more effective in measuring stronger earthquakes (M_w 5 and above) than the Richter scale.



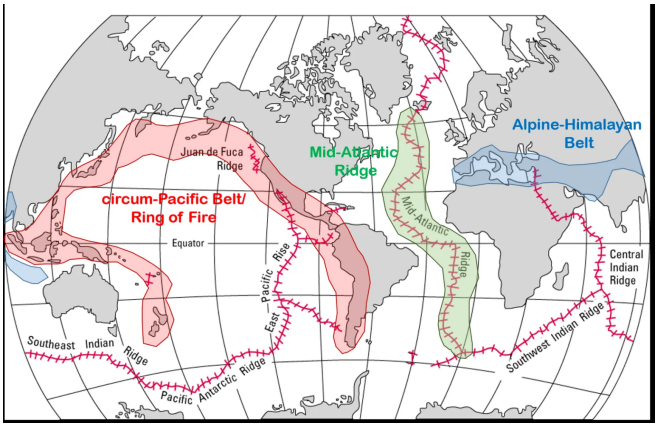
Credit: GeologyIn

Faults.

Where do earthquakes come from? Fortunately for some (and unfortunately for others), nearly 81% of earthquakes occur in a very tectonically-active region called the **circum-Pacific Belt** (popularly known as the **Ring of Fire**).

The next most tectonically-active seismic belt is the **Alpine-Himalayan Belt** where 17% of the world's earthquakes occur. The rest of the earthquakes occur along the **Mid-Atlantic Ridge** in the Atlantic Ocean.

Earthquakes along the seismic belts originate from convergent plate boundaries. The contact between the two interacting plates is called **megathrust faults** which can produce earthquakes of M_w 9.0 and above.



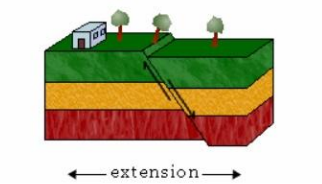
Modified from USGS

Natural or man-made events can cause earthquakes.

Earthquakes caused by the eruption of volcanoes are called **volcanic earthquakes**. Generally, small earthquakes called **collapse earthquakes** occur when underground caves or mines collapse. The detonation of explosives can also cause earthquakes called **explosion earthquakes**.

The most common type of earthquake, **tectonic earthquakes**, are caused by fault movement. There are main types of faults:

1. Normal Faults



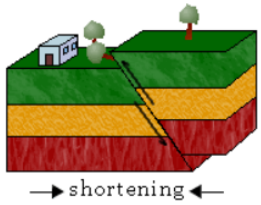
Credit: Windup Radio

In a normal fault, the hanging wall moves down relative to the footwall.

Fun fact: Miners coined the term “hanging wall” to refer to the wall where they would hang their lamps and “footwall” for the surface on which they walk.

Normal faults are the result of **tensional forces** that pull the two slabs apart. They are also known as tensional faults, gravity faults, or normal-slip faults.

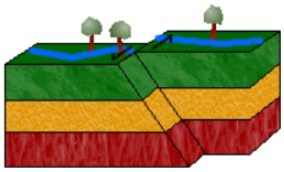
2. Reverse Faults



Credit: Windup Radio

In a reverse fault, the hanging wall moves up relative to the footwall. This type of fault is the result of **compressional forces** that push the two slabs together, shoving the hanging wall above the underlying block. These faults are also known as thrust faults, compression faults, or reverse-slip faults.

3. Strike-Slip Faults



Credit: Windup Radio

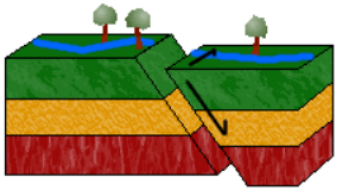
In a strike-slip fault, blocks move horizontally with respect to one another due to **shearing forces**.

Left-lateral strike-slip faults (or **sinistral faults**) occur when one block moves to the left relative to the other block. **Right-lateral strike-slip faults** (or **dextral faults**) occur when the block moves to the right.

An easy way of distinguishing between the two is imagining yourself standing on one block, facing the other block. If the block on the other side moves to the left, the movement is left-lateral. If it moves to the right, right-lateral.

Can you guess the movement of the strike-slip fault in the animation above? *The answer: left-lateral.*

4. Oblique-Slip Faults



Credit: Windup Radio

A combination of shearing forces and tensional or compressional forces would result in an oblique-slip fault, pictured above.

Earthquake-related Hazards

As we all know, major earthquakes can have devastating effects on both living and nonliving things. Depending on the destructive force of the earthquake, it can cause the following events:

1. Landslides and Ground Subsidence

These are caused by ground shaking during an earthquake.

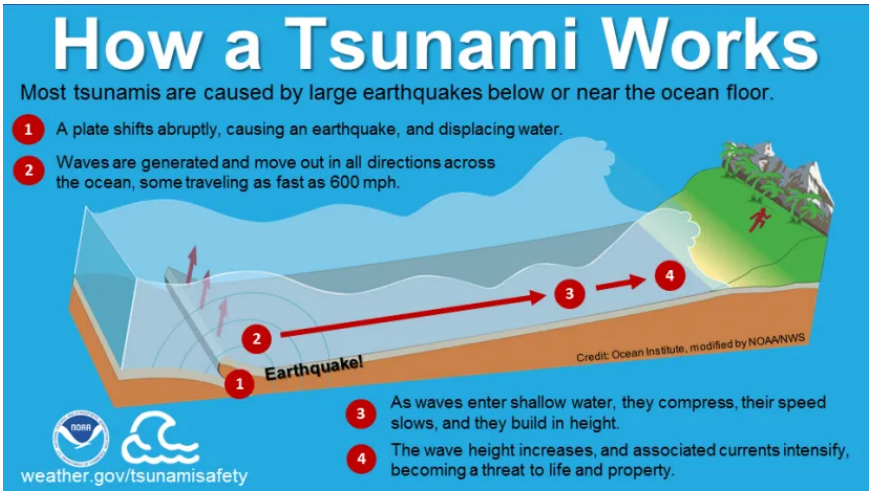
A **landslide** is a form of mass wasting where large amounts of earth move down a slope under the influence of gravity. They can have devastating effects especially in heavily populated areas near hillsides or mountain slopes.

Subsidence is the sudden sinking of the Earth's surface due to the movement of the earth underneath. **Liquefaction** is similar to subsidence but occurs when sediments are saturated with water. While these events can occur naturally, they are usually aggravated by earthquakes.

2. Flooding and Water-related Hazards

During and after an earthquake, large water pipes underground and dams may be damaged and fail. These can cause flooding in populated areas which may result in property damage and harm to life.

In enclosed bodies of water such as lakes or reservoirs, waves called **seiches** may occur. These are oscillating waves that produce major fluctuations in the water level, depending on the strength of the earthquake.



Credit: DDMBVI

One of the most dangerous effects of earthquakes that originate offshore are tsunamis.

Tsunamis are giant waves that are produced when a fault displaces a large slab of the ocean floor They are nearly undetectable in the open ocean, but once tsunamis reach shallow waters, wave height increases dramatically and can reach up to 30 m, like what happened in the 2004 Indian Ocean M_w 9.1 Megathrust Earthquake in Sumatra, Indonesia.

3. Damage to Man-made Structures

Depending on the material used and the way they were constructed, structures such as buildings, bridges, roads, dams, and others are susceptible to damage.

Damage can range from cracks on the walls to the total destruction of property. Fires can also break out due to severed gas and electrical lines. Coupled with broken water pipelines, even small fires can quickly spread and cause massive damages.

Spillage of hazardous chemicals from factories and chemical containment facilities is also a possible threat, such as the leakage of radioactive water from the Fukushima nuclear power plant during the 2011 Japan Earthquake.