

Earthquake



What is it?



Can we predict it?

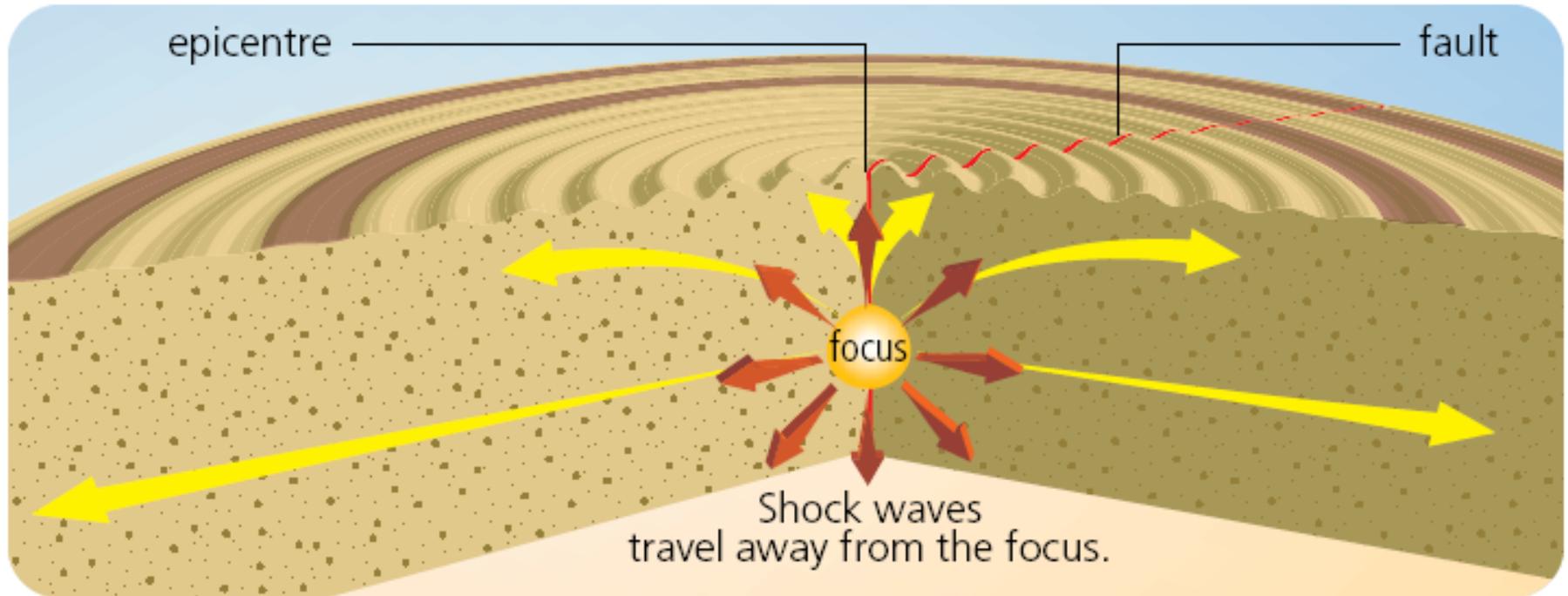
What is an earthquake?

Earthquake is the **vibration (shaking) and/or displacement of the ground** produced by the **sudden release of energy**.

- Rocks under *stress* accumulate *strain energy* over time.
- Stress results from tectonic plate movement, magmatic or volcanic activity.
- When stress exceeds strength of rocks, rock breaks and slips.
- Rock slippage/rupture occurs at the weakest point (*fault*).
- Strain energy is released as **seismic waves**.



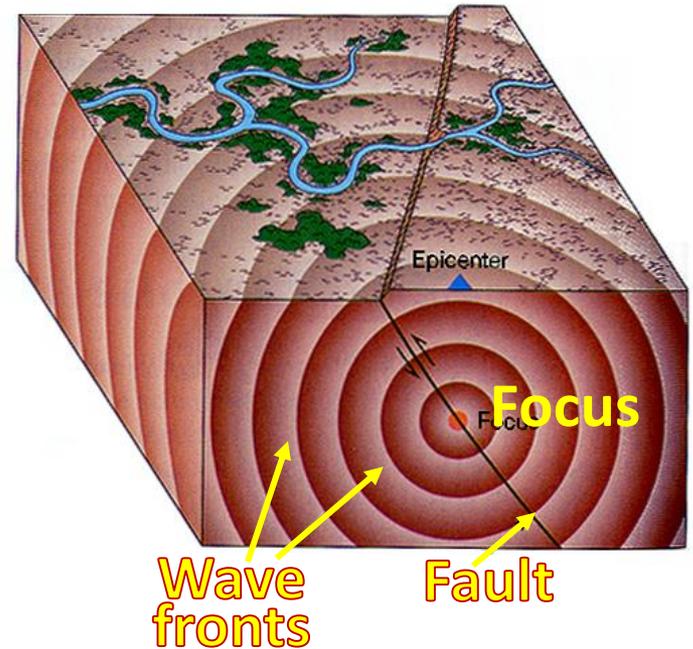
Focus and Epicenter



- **Focus** – point inside the Earth where an earthquake begins (*point of initial rupture*). The majority of tectonic earthquakes originate in depths not exceeding tens of kilometers.
- **Epicenter** – point on the surface of the Earth directly above the focus where the shaking is usually felt most strongly.

Seismic Waves

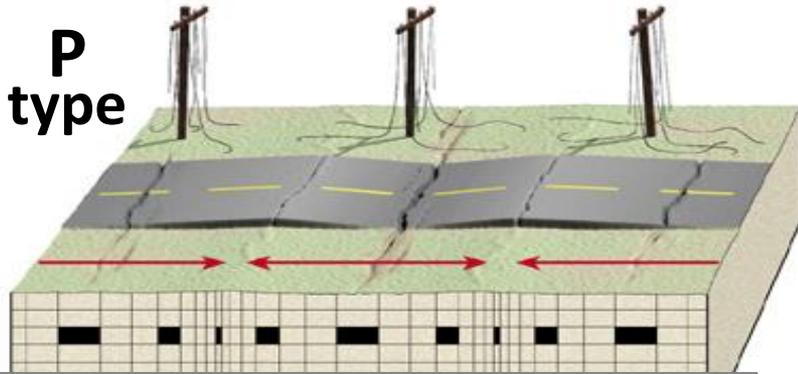
- Energy released from the earthquake source (its focus) radiates in all directions.
- Energy is in the form of waves called **seismic waves**.
- Earthquakes create distinct types of seismic waves that travel through the Earth's layers with different velocities:
 1. Body waves - travel through the Earth interior (*travel fast*).
 2. Surface waves - travel on the Earth surface (*travel slow – more destructive!*).



Types of Seismic Waves

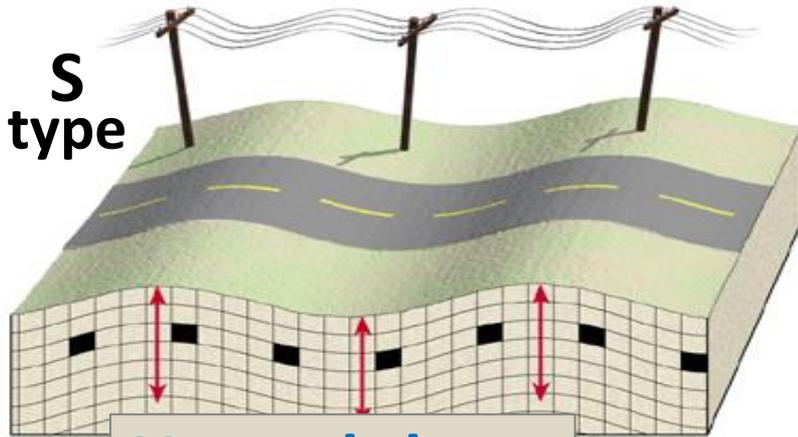
BODY WAVES

P
type



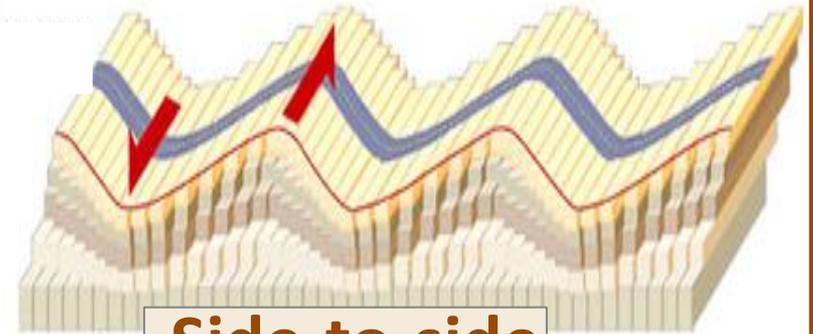
Compression-expansion

S
type

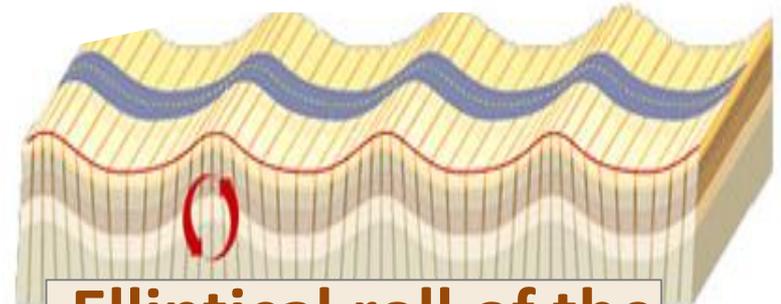


Up-and-down

SURFACE WAVES



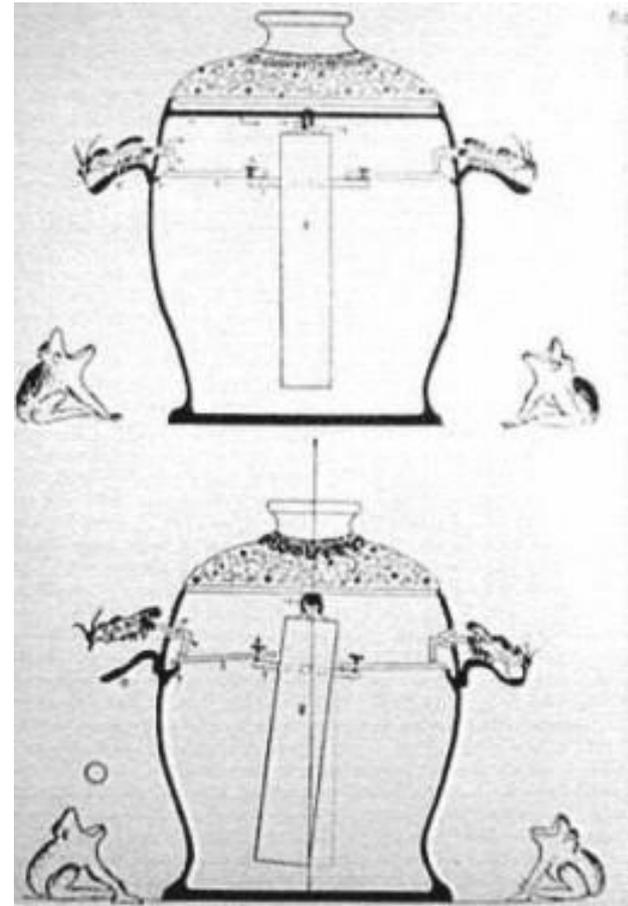
**Side-to-side
horizontal
movement**



**Elliptical roll of the
ground oriented
vertically**

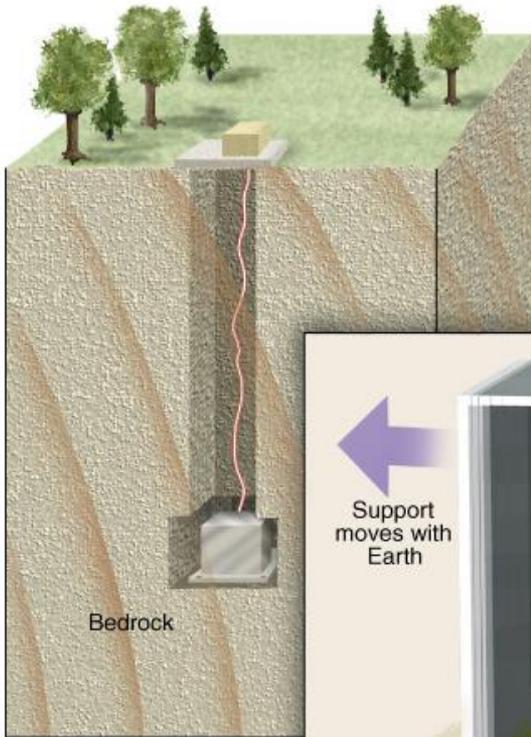
Detecting an Earthquake

Chinese created the first earthquake detector
2000 years ago!



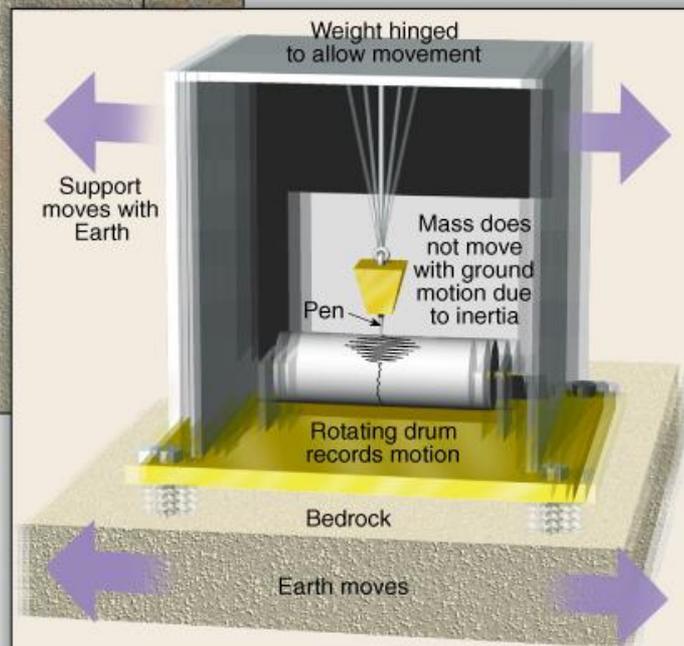
Measuring an Earthquake

Earthquakes are measured using observations from **seismographs**, instruments that record seismic waves.

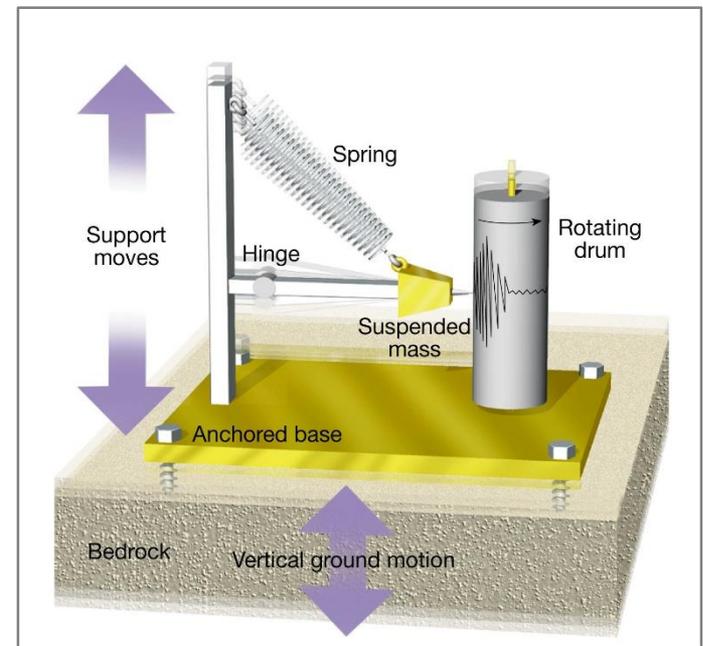


Different *seismograph* types are needed to record both vertical and horizontal ground motion:

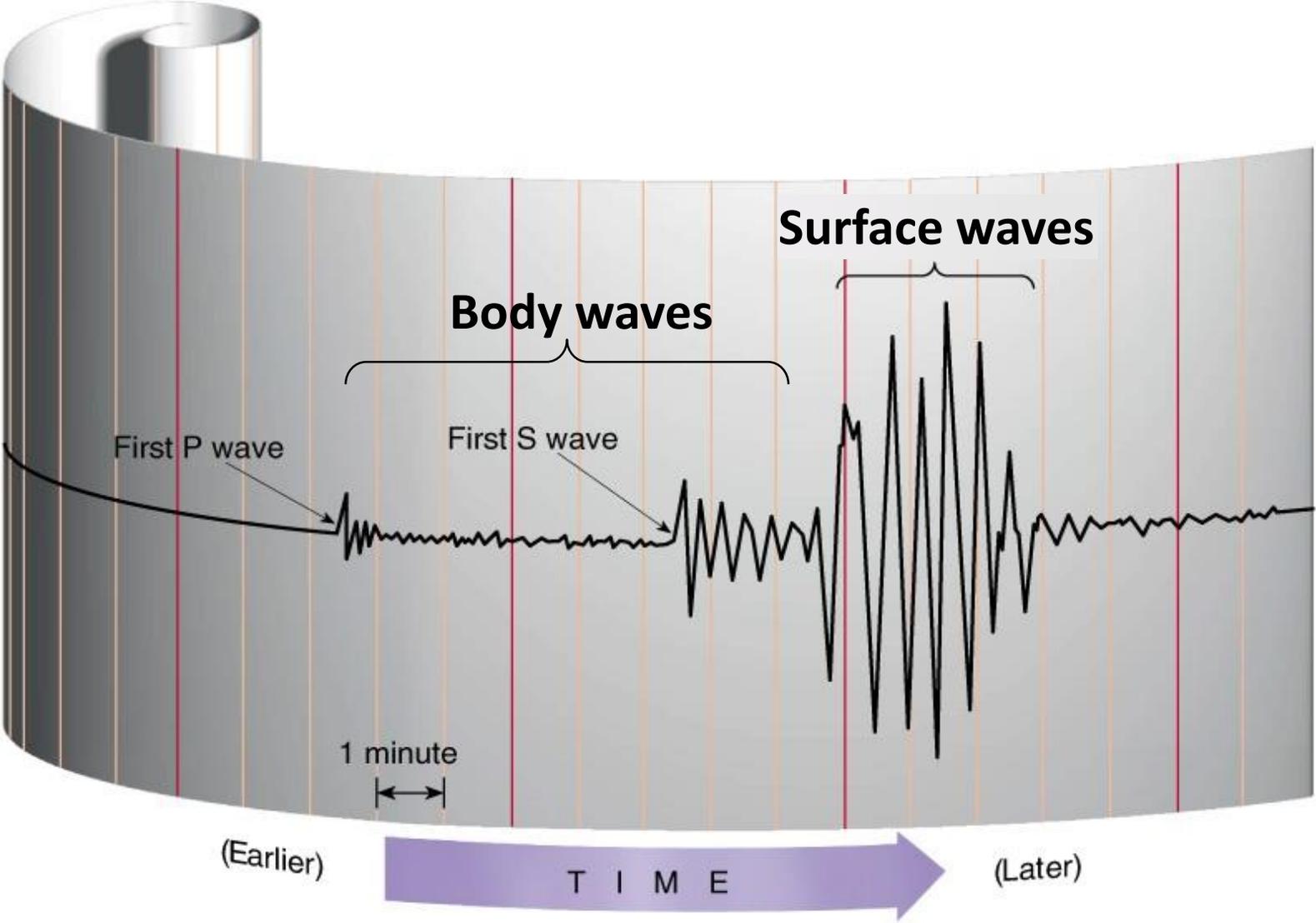
Horizontal



Vertical

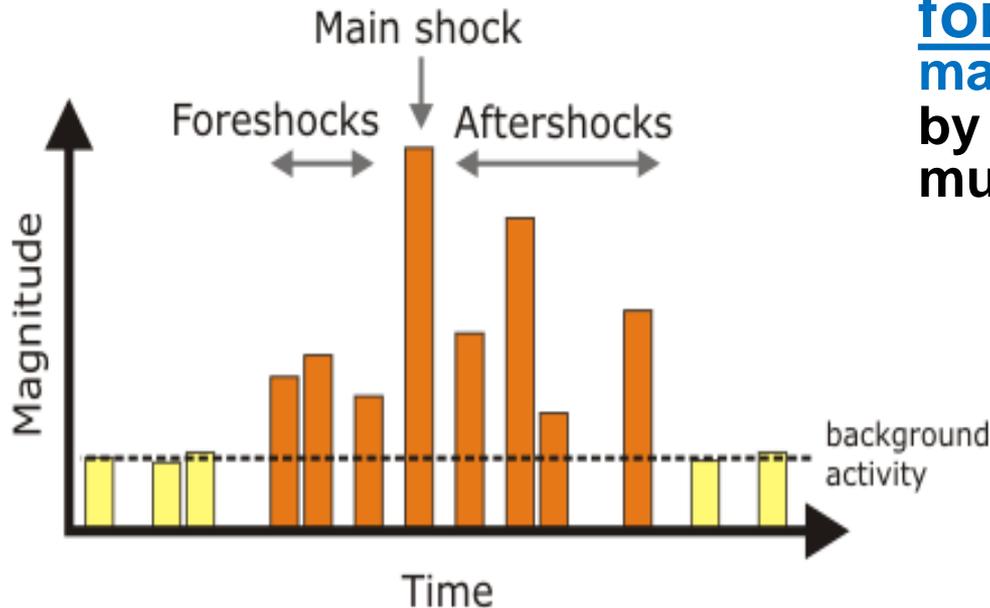


Simplified Seismogram



Foreshocks and Aftershocks

Earthquakes often occur as a sequence rather than individual events:



- Small earthquakes, called **foreshocks**, often precede a **major earthquake (main shock)** by days or, in some cases, by as much as several years.
- **Adjustments of crust** (redistribution of stress on the fault) that **follow a major earthquake** often generate smaller quakes in the same area called **aftershocks**.

- **Bigger** earthquakes often have *more and larger* aftershocks and the sequences can last for years.
- **Earthquake swarms** are **sequences of earthquakes** striking in a specific area within a short period of time in which **no single earthquake has notably higher magnitudes** than the other.

Measuring Earthquakes

Two measurements that describe the “power” or “strength” of an earthquake are:

- **Intensity** – a measure of the **degree of earthquake shaking** at a given locale based on the amount of damage.
- **Magnitude** – estimates the **amount of energy** released at the source of the earthquake:
 - Logarithmic scale (not linear).
 - Magnitude 2 or lower earthquakes cannot be felt by humans.
 - Magnitude 7 and over potentially cause serious damage over larger areas, depending on their depth.
 - The **largest earthquakes in historic times** have been of magnitude **slightly over 9**, although there is no limit to the possible magnitude.

Earthquake Magnitude and Energy Equivalence

One unit of magnitude increase corresponds to ~10-fold increase in wave amplitude and ~30-fold energy increase.

Earthquake Magnitude	Energy Released* (Millions of Ergs)	Approximate Energy Equivalence
0	630,000	1 pound of explosives
1	20,000,000	
2	630,000,000	Energy of lightning bolt
3	20,000,000,000	
4	630,000,000,000	1000 pounds of explosives
5	20,000,000,000,000	
6	630,000,000,000,000	1946 Bikini atomic bomb test 1994 Northridge Earthquake
7	20,000,000,000,000,000	1989 Loma Prieta Earthquake
8	630,000,000,000,000,000	1906 San Francisco Earthquake 1980 Eruption of Mount St. Helens
9	20,000,000,000,000,000,000	1964 Alaskan Earthquake 1960 Chilean Earthquake
10	630,000,000,000,000,000,000	Annual U.S. energy consumption

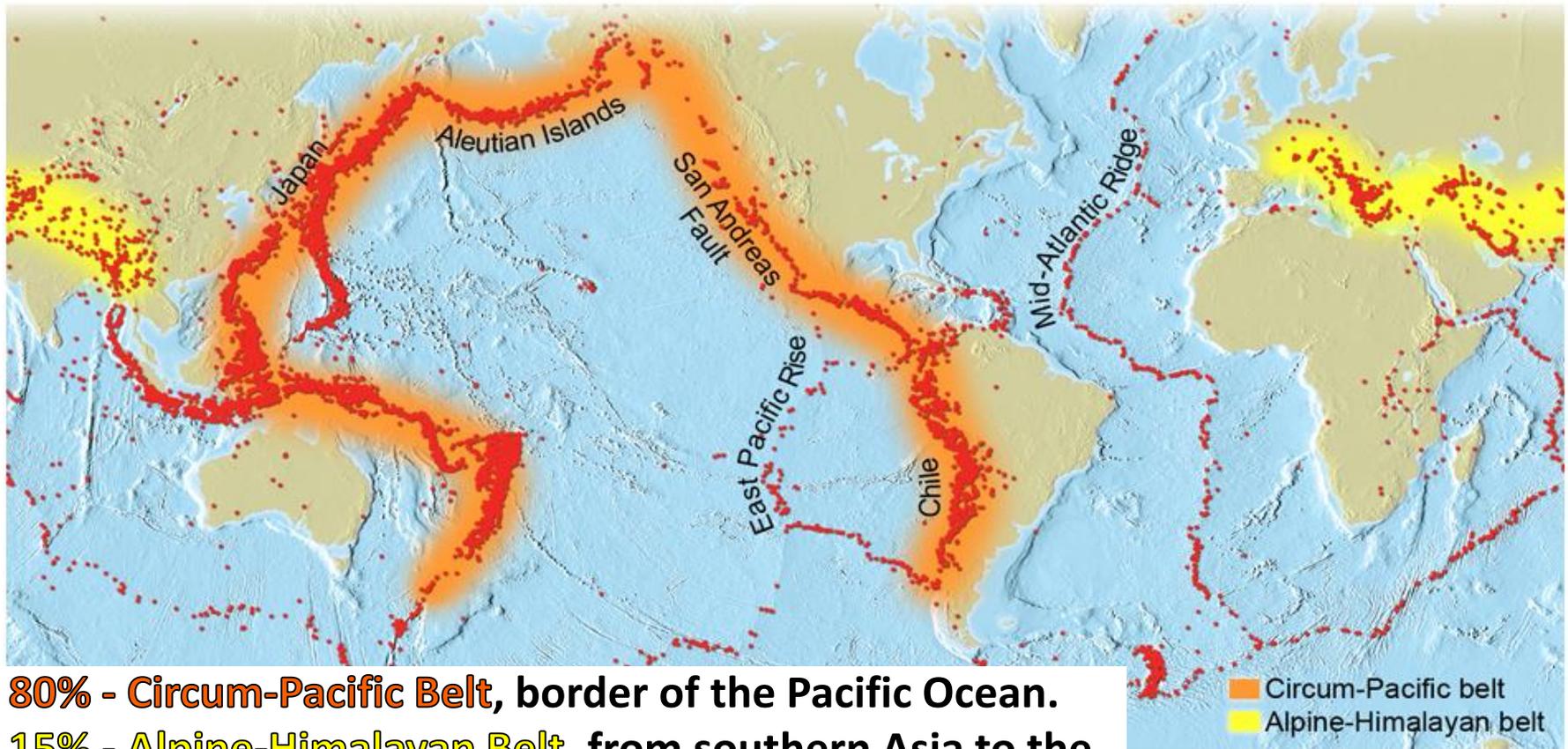
Modified Mercalli Scale vs. Richter Scale



Intensity category	Effects	Magnitude scale
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8

Earthquakes Around the World

Earthquakes happen around tectonic plate boundaries.



80% - Circum-Pacific Belt, border of the Pacific Ocean.

15% - Alpine-Himalayan Belt, from southern Asia to the Mediterranean region.

5% - parts of the Arctic, Atlantic, and Indian Oceans.

Antarctica and **Australia** experience the least amount of earthquake activity then any other areas of the world.

Graph shows 15,000 larger magnitude (>5) earthquakes over 10-year period.

How common are earthquakes?

- It is estimated that **around 500,000 earthquakes occur each year**, detectable with current instrumentation.
- About **100,000** of these **can be felt** (ground shaking during a moderate to large earthquake typically lasts about 10 to 30 seconds).
- **Minor earthquakes occur nearly constantly** around the world; **larger earthquakes occur less frequently**.
- While most earthquakes are caused by movement of the Earth's tectonic plates, the following human activities can also produce earthquakes:
 - storing large amounts of water behind a dam
 - drilling and injecting liquid into wells
 - coal mining and oil drilling

Additional Information

<http://earthquake.usgs.gov/learn/animations/>

<http://earthquake.usgs.gov/learn/facts.php>