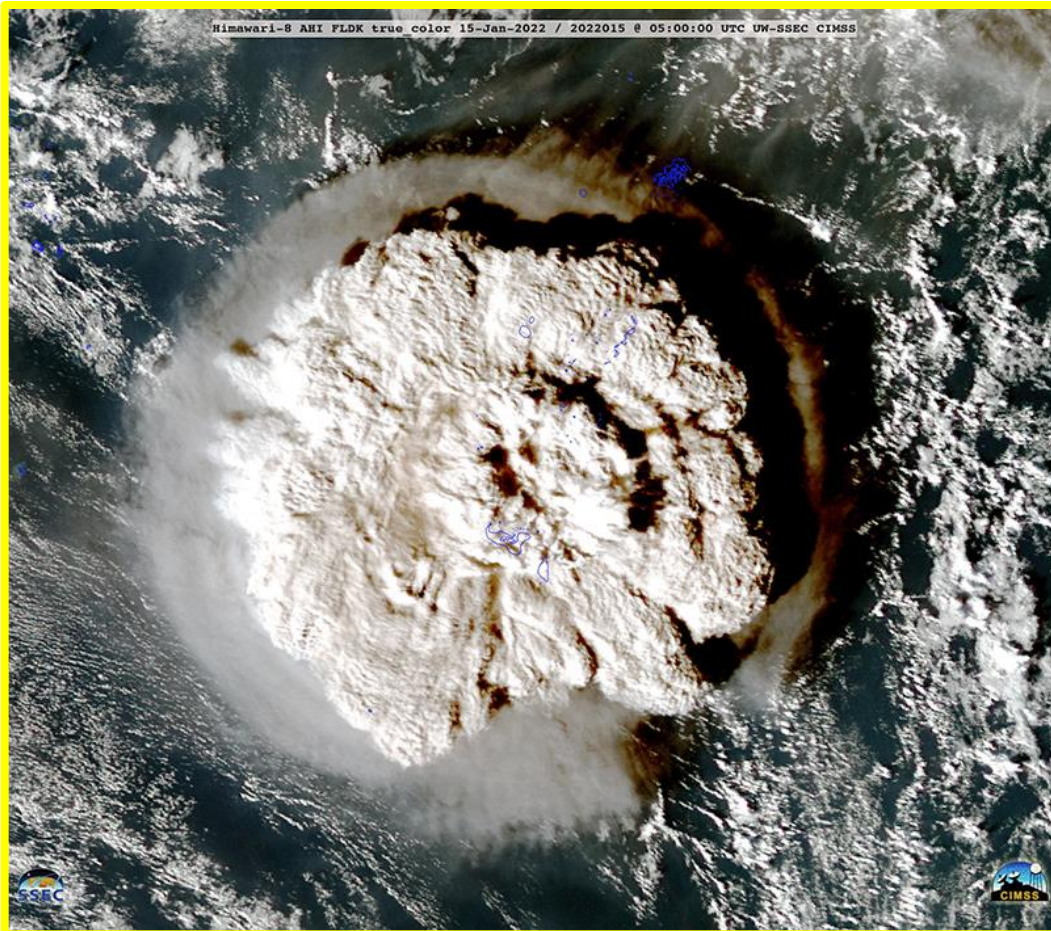


The Most Powerful Volcanic Eruption of the 21st Century

Hunga Tonga-Hunga Ha'apai, 14-15 January 2022



- Blast as powerful as Krakatoa - biggest *boom* ever recorded!
- Ejected $\sim 2 \text{ mi}^3$ of material; generated an ash plume half the size of France.



Earthquakes

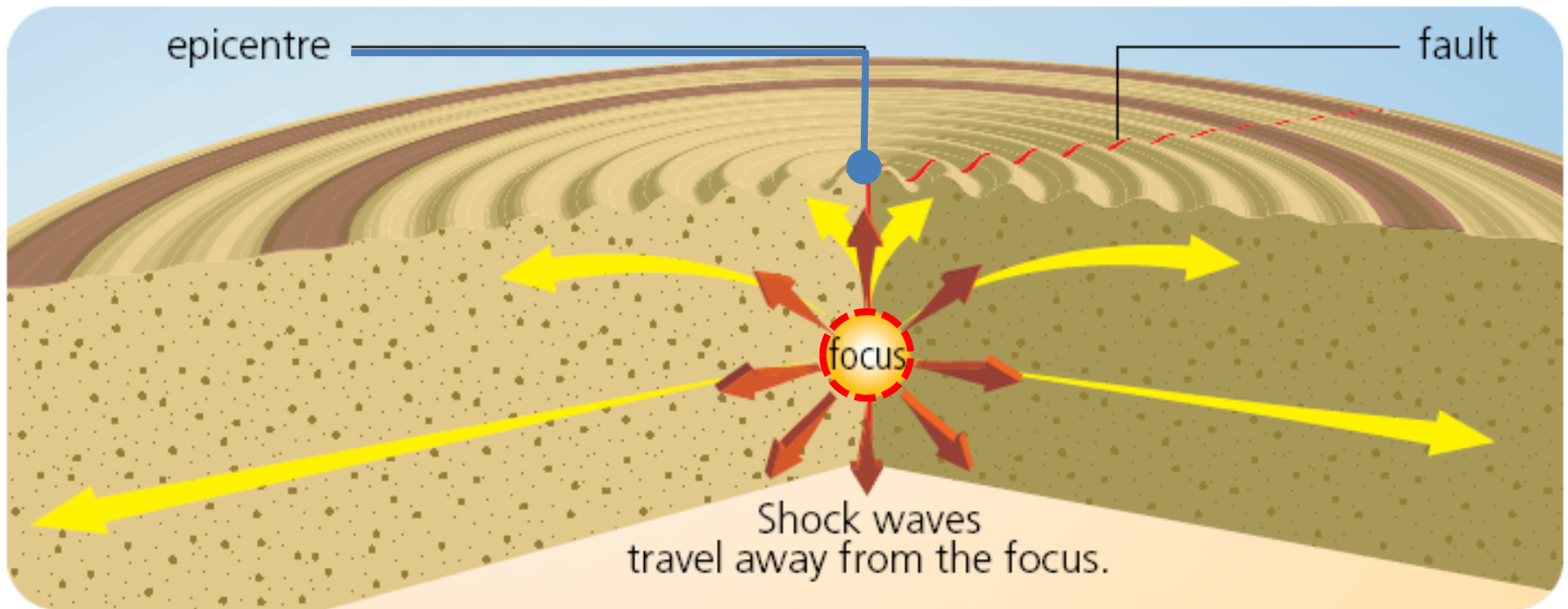
What is an earthquake?

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**.



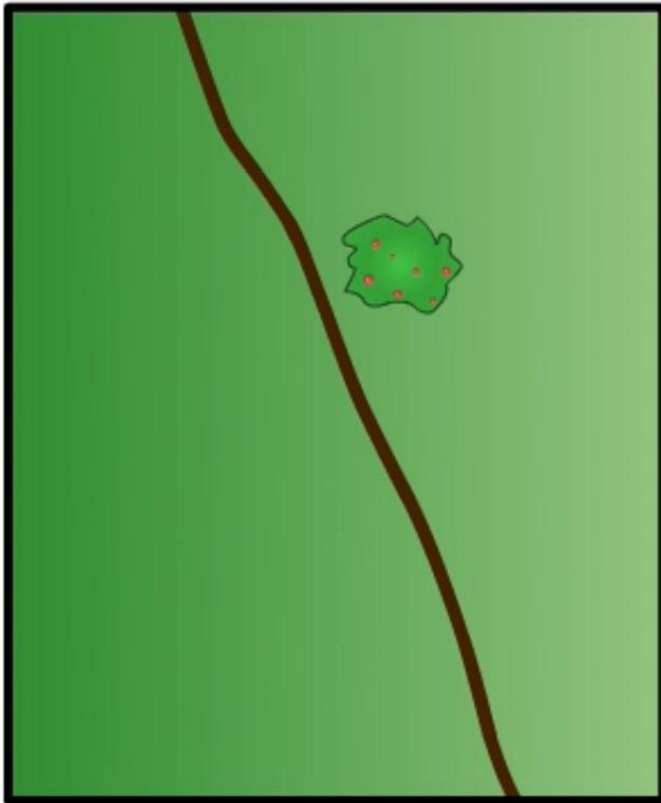
Focus and Epicenter



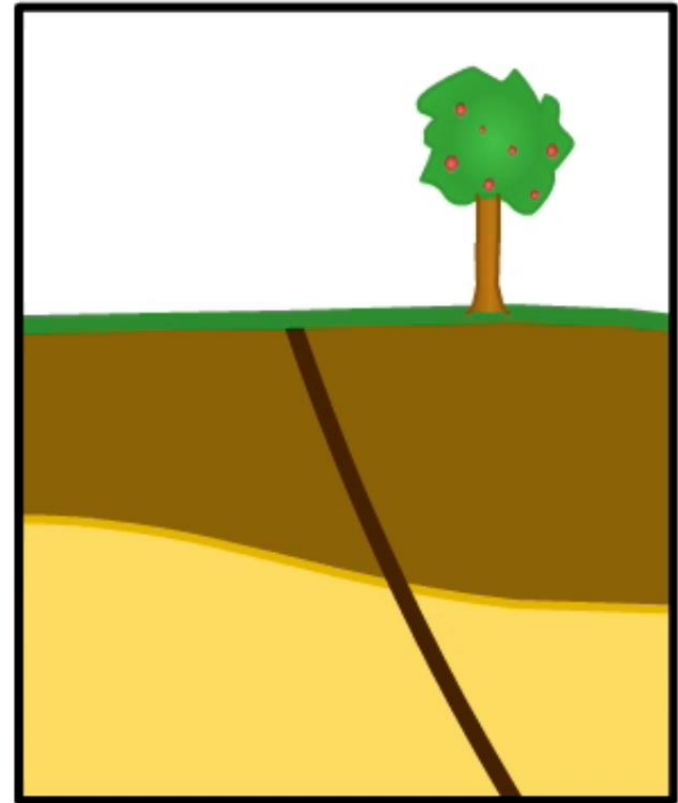
- **Focus** – point inside the Earth where an earthquake begins (*point of initial rupture*). The majority of tectonic earthquakes originate in depths not exceeding tens of kilometers.
- **Epicenter** – point on the surface of the Earth directly above the focus where the shaking is usually felt most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

Earthquakes often occur as a **sequence rather than individual events**

● Foreshock ● Mainshock ● Aftershock

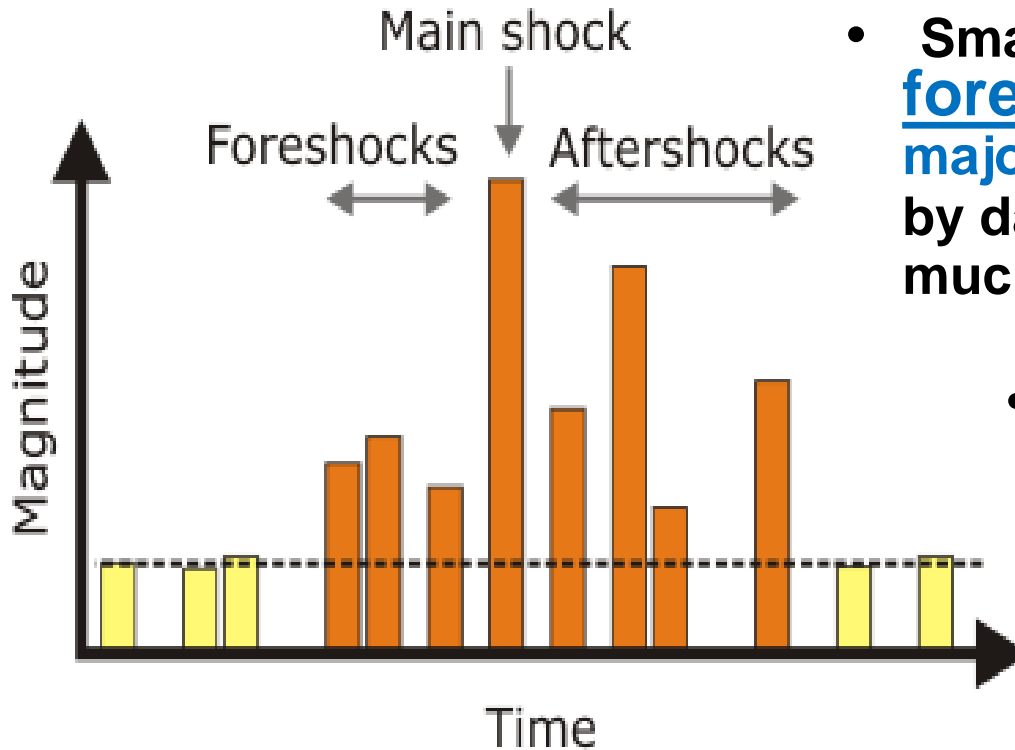


Map View



Cross-Section View

Foreshocks and Aftershocks



- 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:

Mercalli
scale

- **Intensity** – a measure of the **degree of shaking** at a given locale based on the amount of damage.

Richter
scale

- **Magnitude** – estimates the **amount of energy** released at the source of the earthquake:
 - Magnitude is a *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.

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 +

Earthquake Magnitude and Energy Equivalence

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

barely
felt →

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