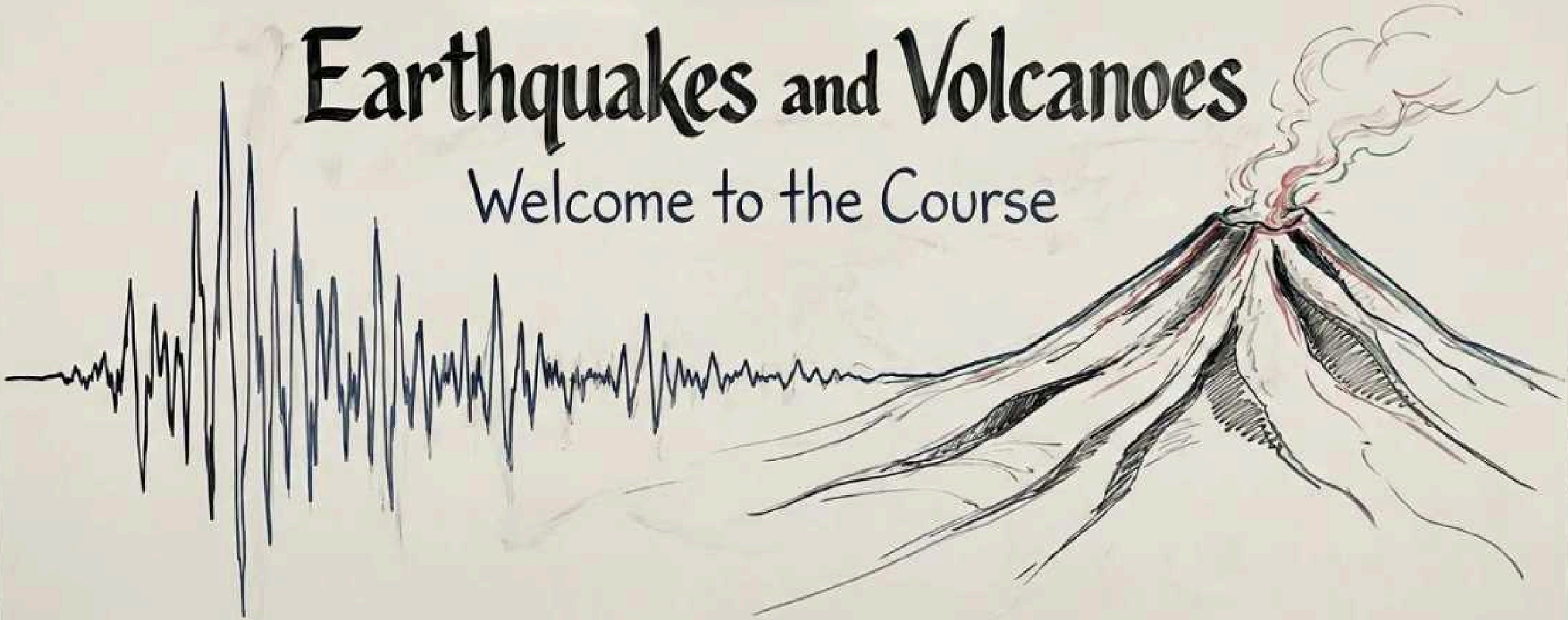
¶ 4.1

GEOL 101 B: Lecture 4

Earthquakes and Volcanoes

Welcome to the Course

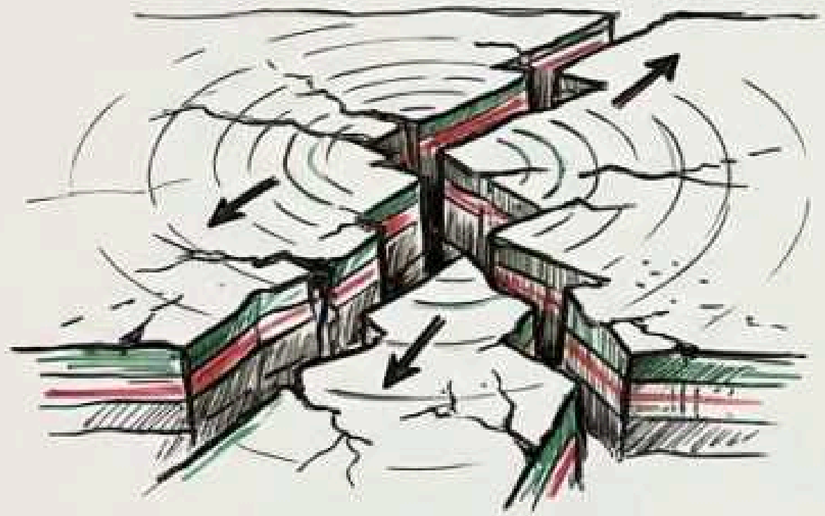


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Earth's Most Dramatic Energy Releases

¶ 4.2

Earthquakes



- Causes
- Location via Seismic Waves
- Magnitude

Volcanoes



- Eruption Mechanics
- Human Impact
- Climate Impact

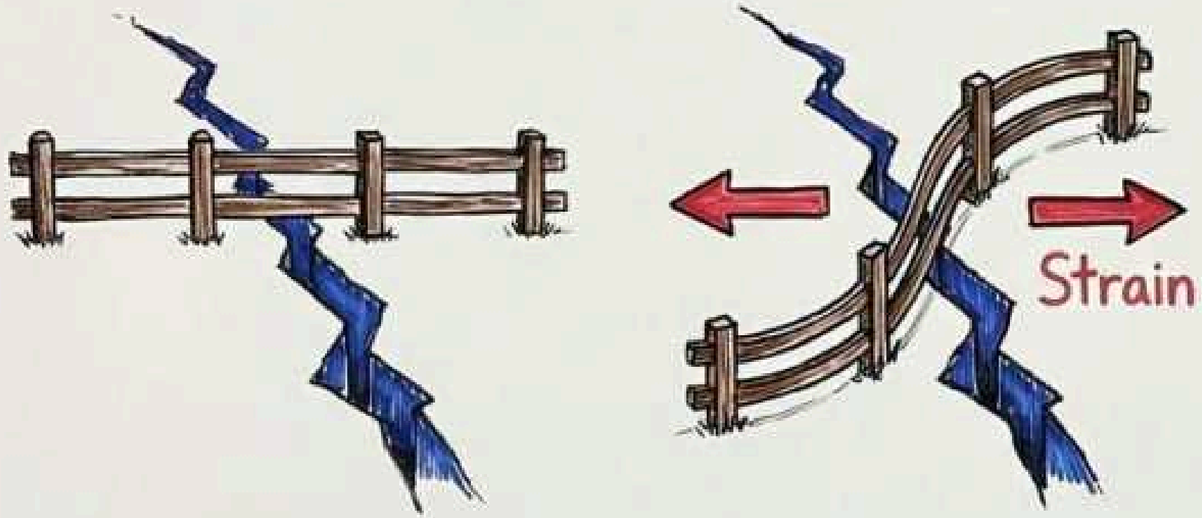
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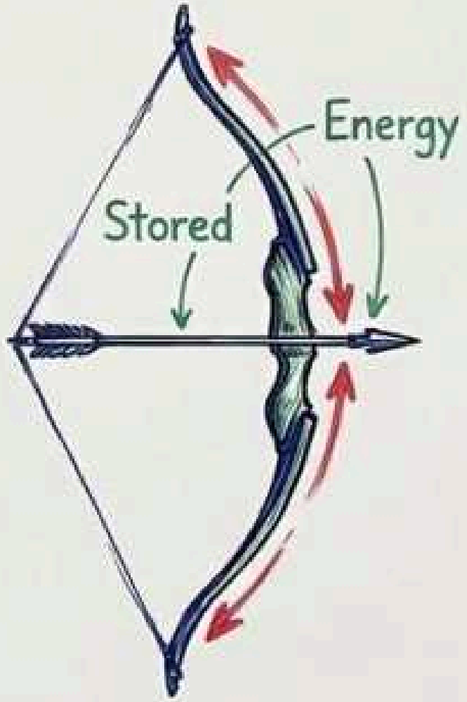
Elastic Rebound (Reid, 1906)

¶ 4.3

Analogy: Rock bending stores energy = Drawn bow.

Process: Slow deformation → Fault slips → Rock snaps back.





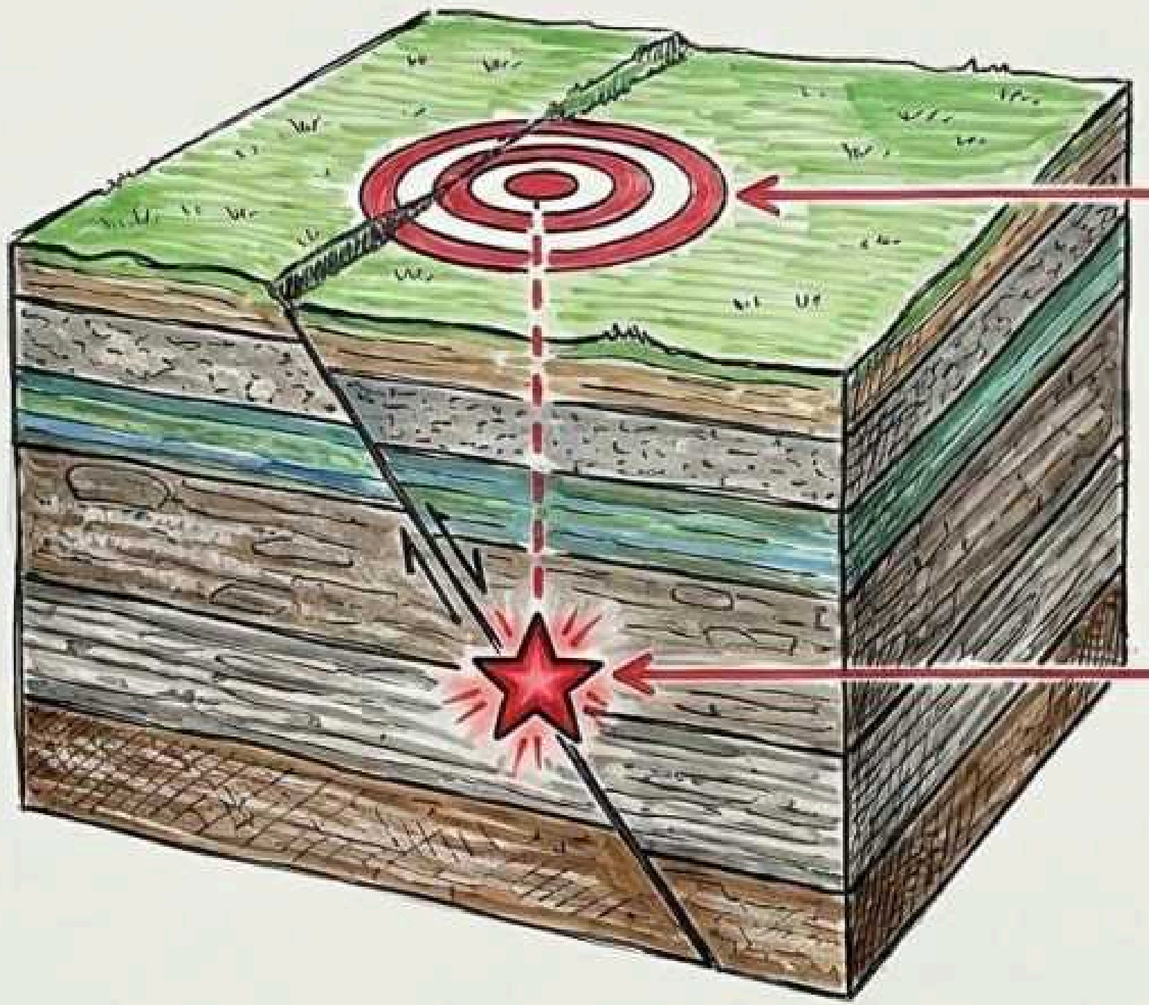
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Anatomy of a Fault

¶ 4.4

Locations: Mostly plate boundaries (grinding); few intraplate (old faults).

Strain Rule:
Stuck longer
= More strain
= Greater release.



Epicenter:
Surface point directly above

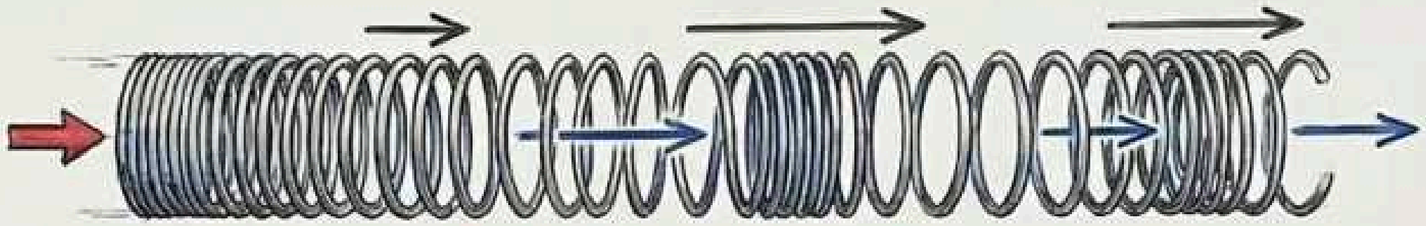
Focus (Hypocenter):
Underground point of slip

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The Three Types of Seismic Waves

¶ 4.5

P Waves (Primary):
Compressional, fastest



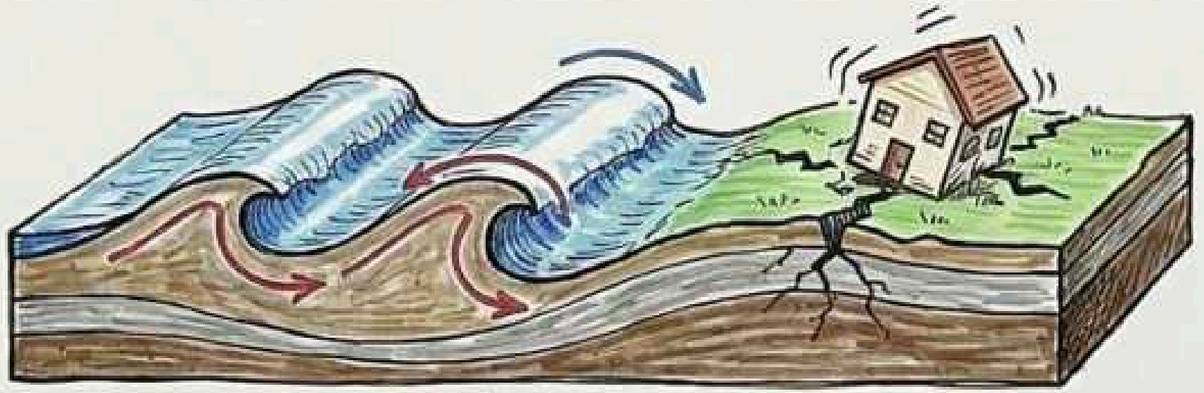
6 km/s in crust

S Waves (Secondary):
Side-to-side, slower



3.5 km/s

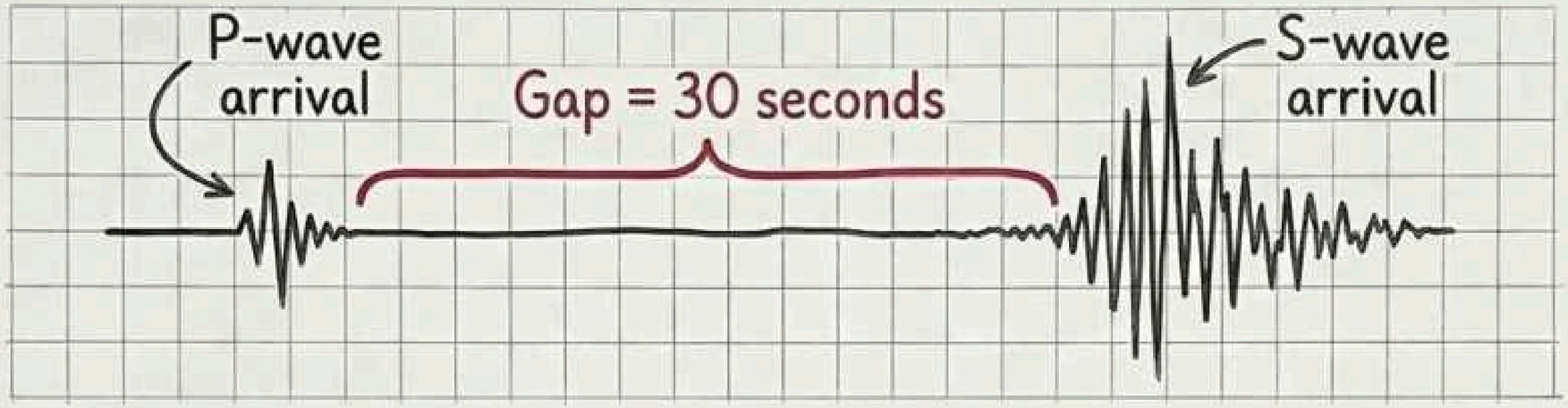
Surface Waves:
Rolling motion, arrive last
cause most damage



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Distance via P-S Wave Delay

¶ 4.6



$$\text{Distance} = \text{Gap} \times \left[\frac{6 \times 3.5}{6 - 3.5}\right]$$

$$\text{Distance} = \text{Gap} \times 8.4$$

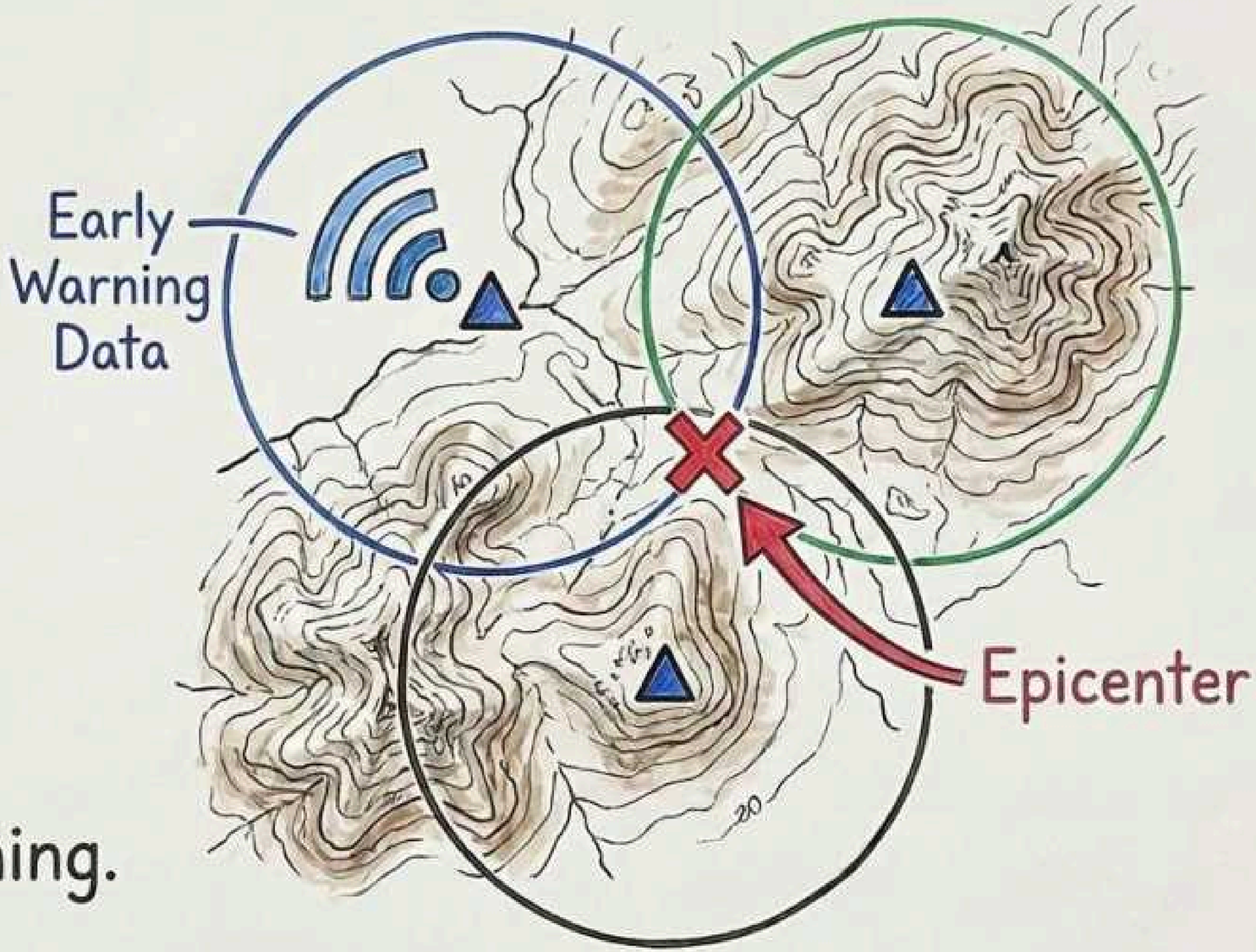
30s gap × 8.4 = 252 km away

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Locating the Epicenter

¶ 4.7

- 1 Station = Distance (Radius)
- 3 Stations = Triangulation (Intersection)
- Modern networks: Automated, provides seconds of early warning.

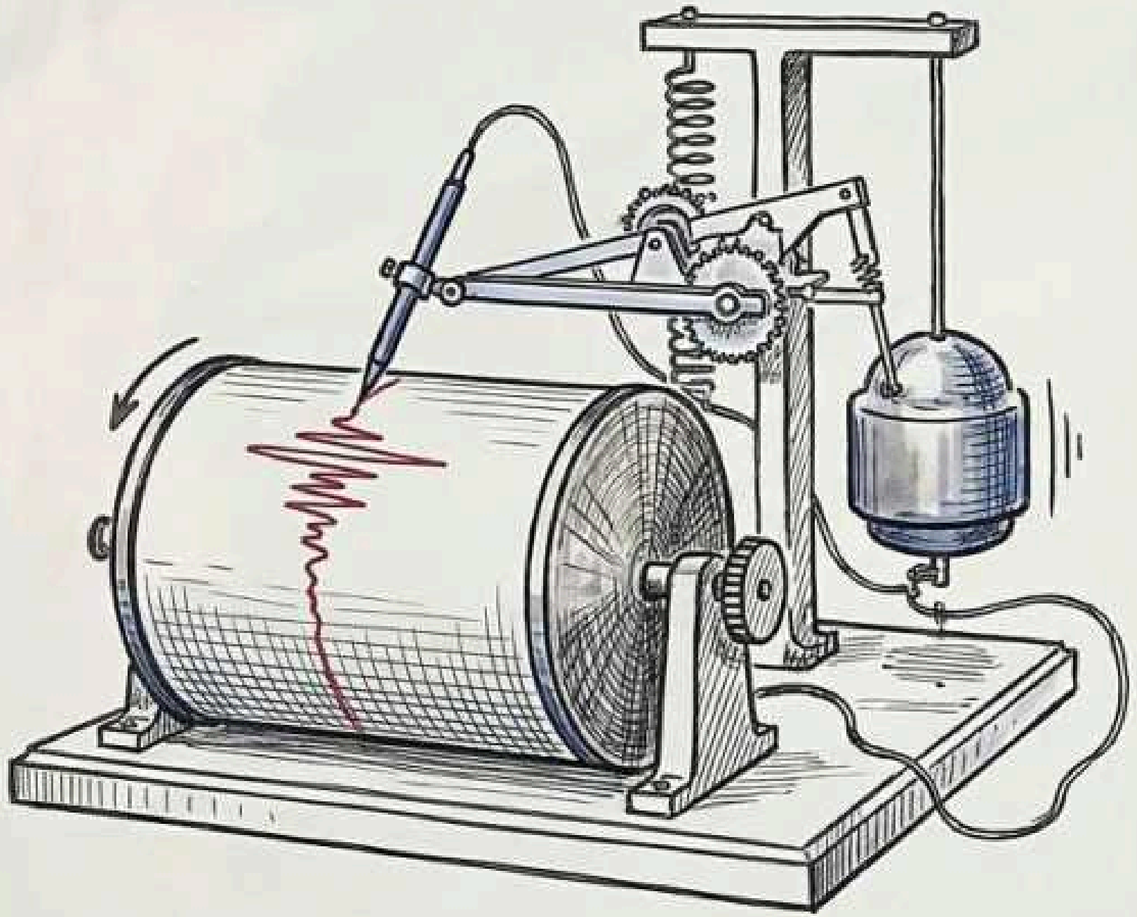


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Evolving Scales of Magnitude

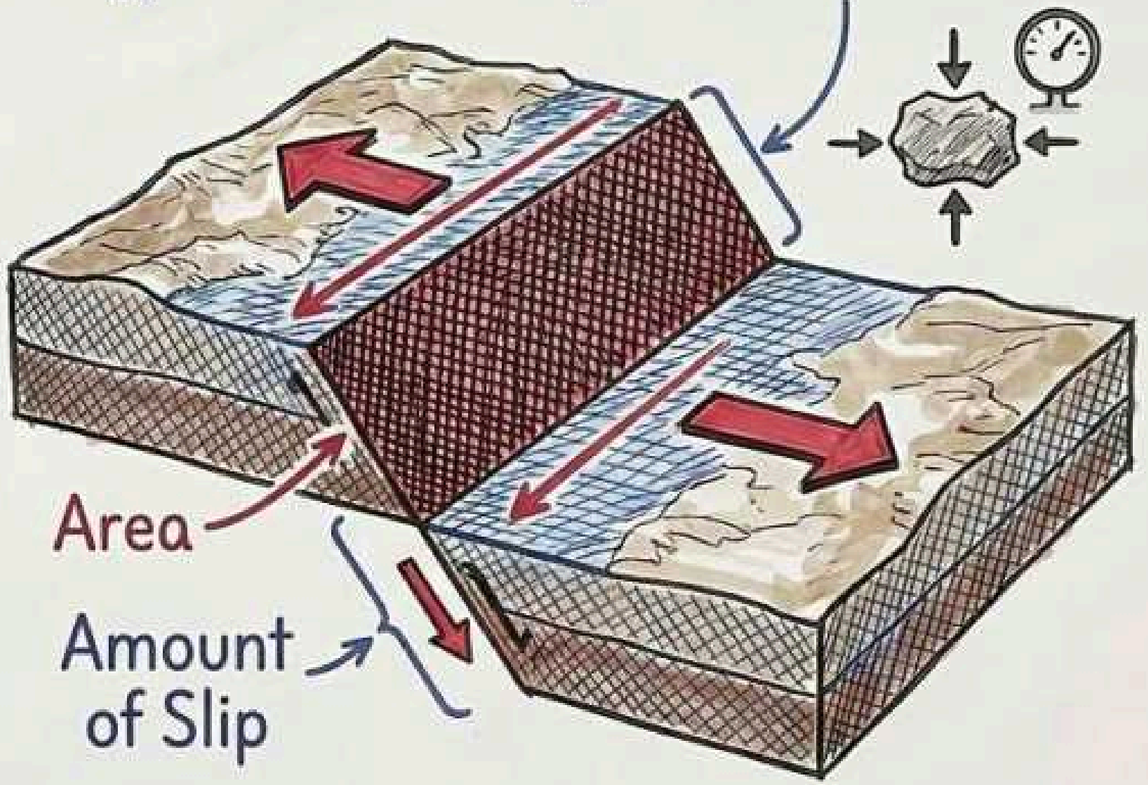
¶ 4.8

Richter Scale (1935): Logarithmic, designed for California.



Moment Magnitude Scale (Modern): Built for large earthquakes.

$$M_W = \text{Area} \times \text{Slip} \times \text{Rock Stiffness}$$

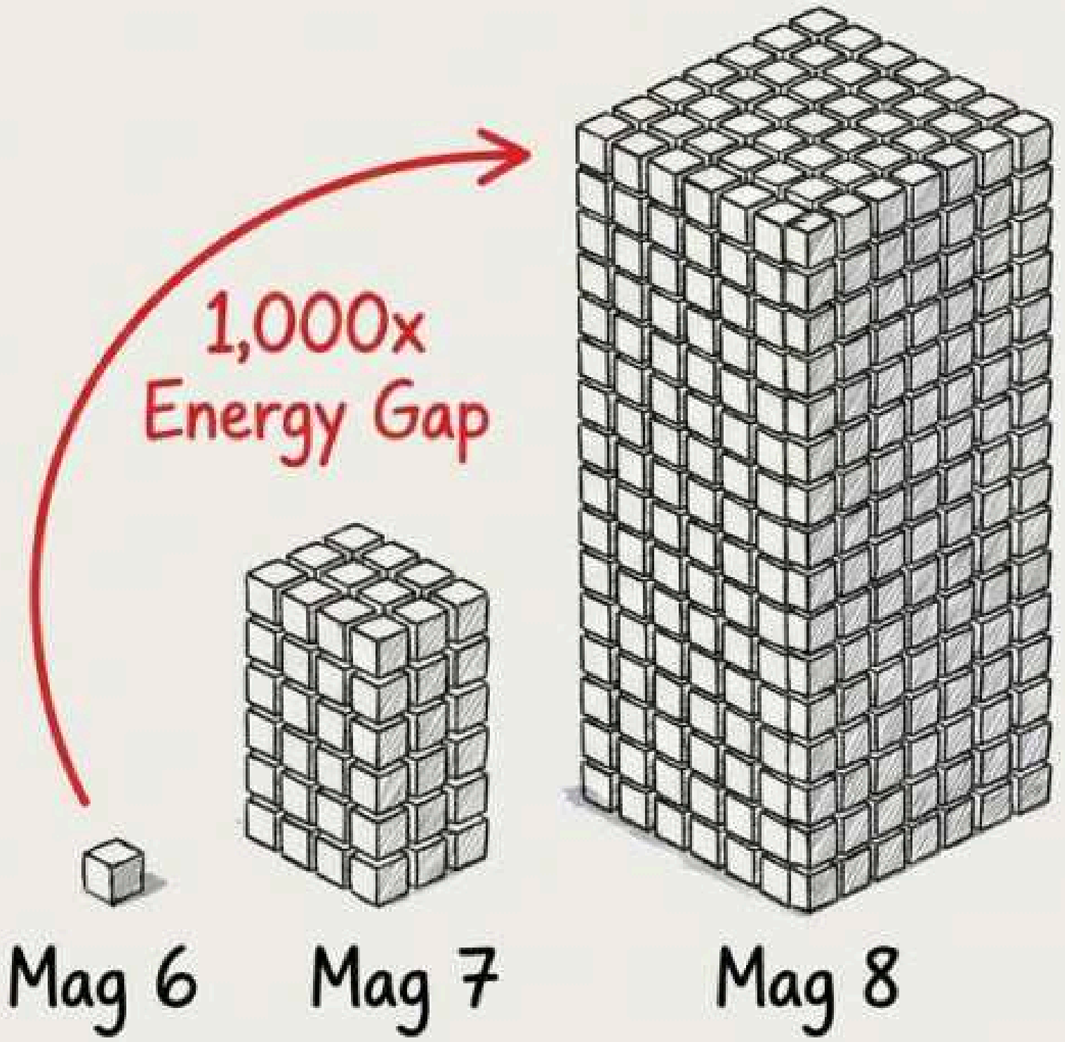


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The Math of Magnitude

¶ 4.9

- Ground Motion:
  +1 Magnitude = 10x motion.
- Energy Release:
  +1 Magnitude = ~32x energy.
- Mathematical constant:
  $10^{1.5} = 31.6$
- Example:
  Mag 8 is 1,000x more energetic than Mag 6 (32 × 32).

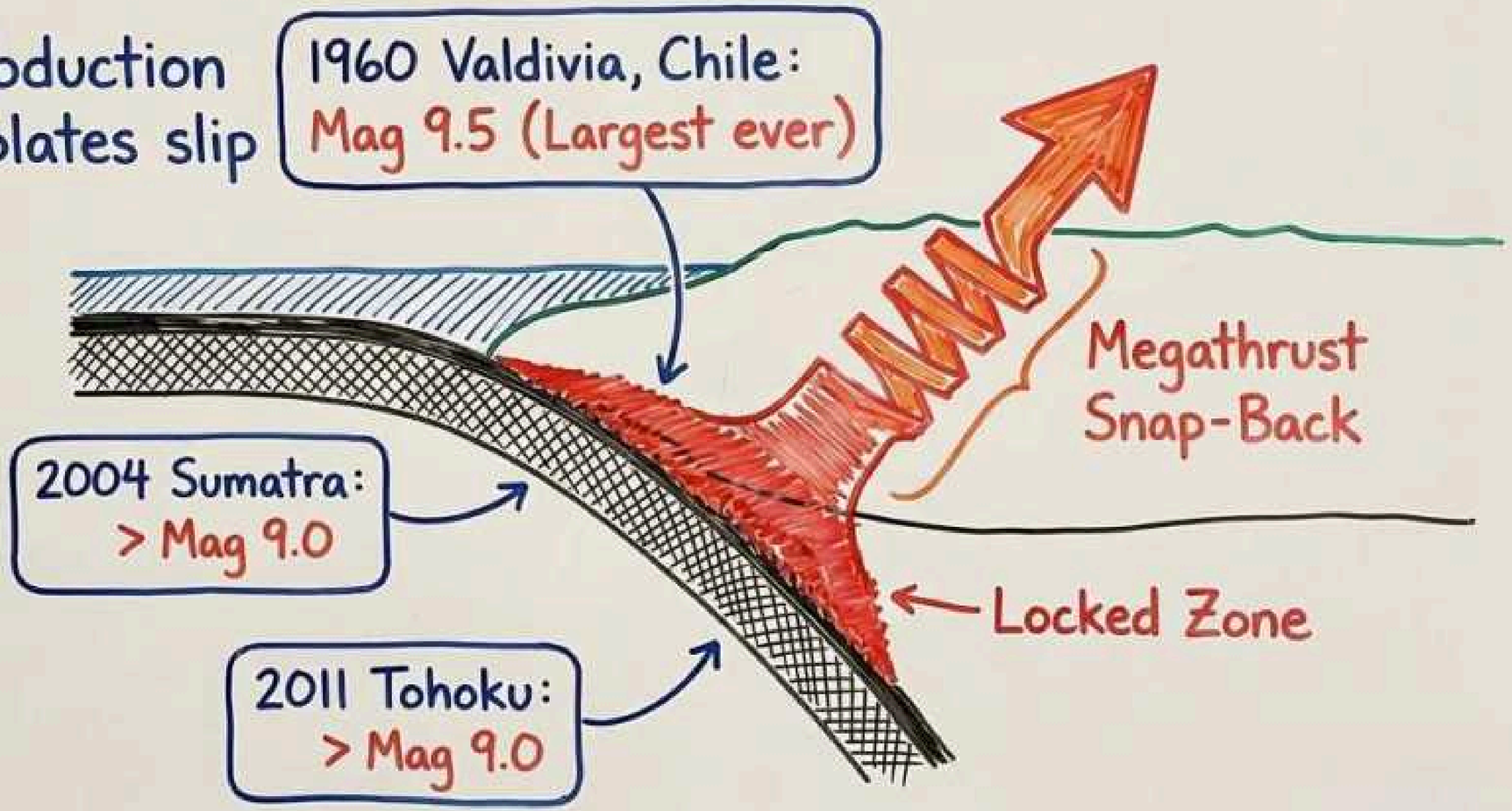


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¶ 4.10

The Largest Recorded Events

Mechanism: Subduction zones (locked plates slip all at once).

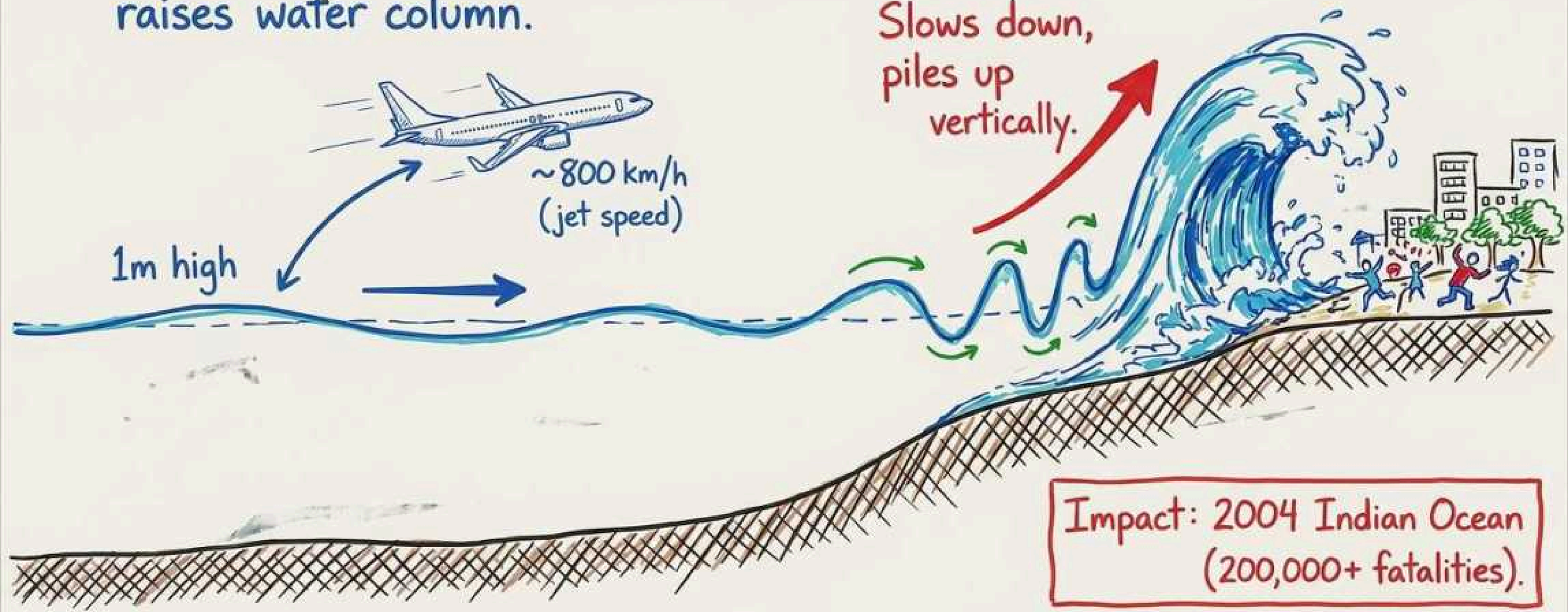


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Tsunami Mechanics

¶ 4.11

- Trigger: Seafloor displacement raises water column.



Impact: 2004 Indian Ocean (200,000+ fatalities).

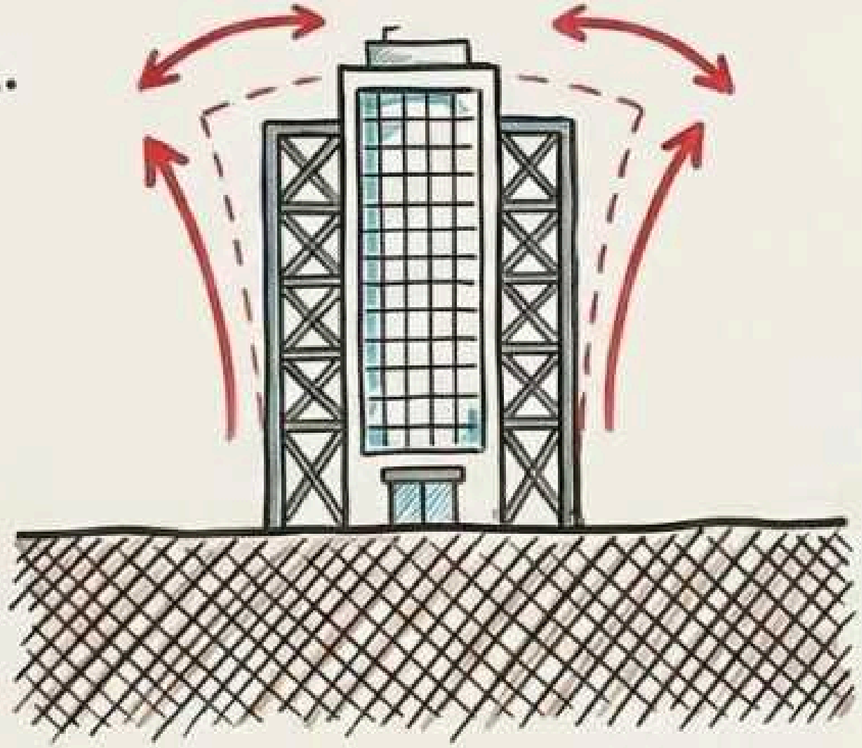
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Why Earthquakes Kill

¶ 4.12

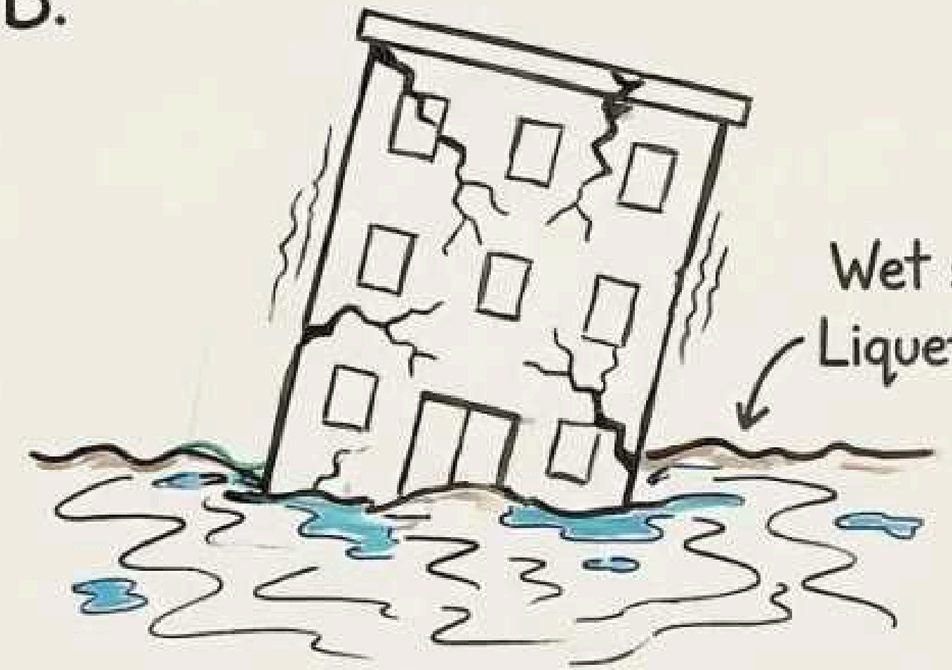
- Primary Cause: Building collapse, not shaking itself.

A.



Mitigation: Strict building codes save lives (even at Mag 7)

B.



Liquefaction: Soft, wet soil turns to liquid under shaking.

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¶ 4.13

Probability, Not Certainty

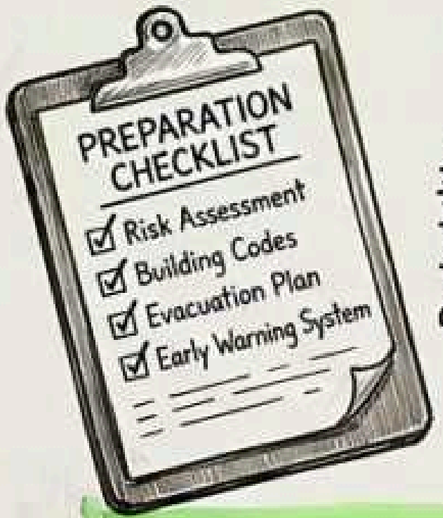
Prediction

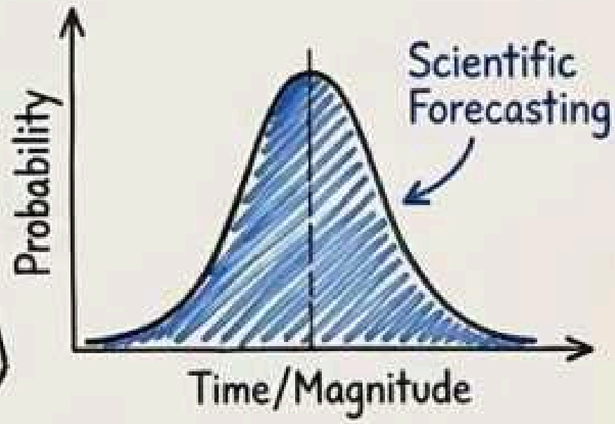
Impossible to say exactly when.

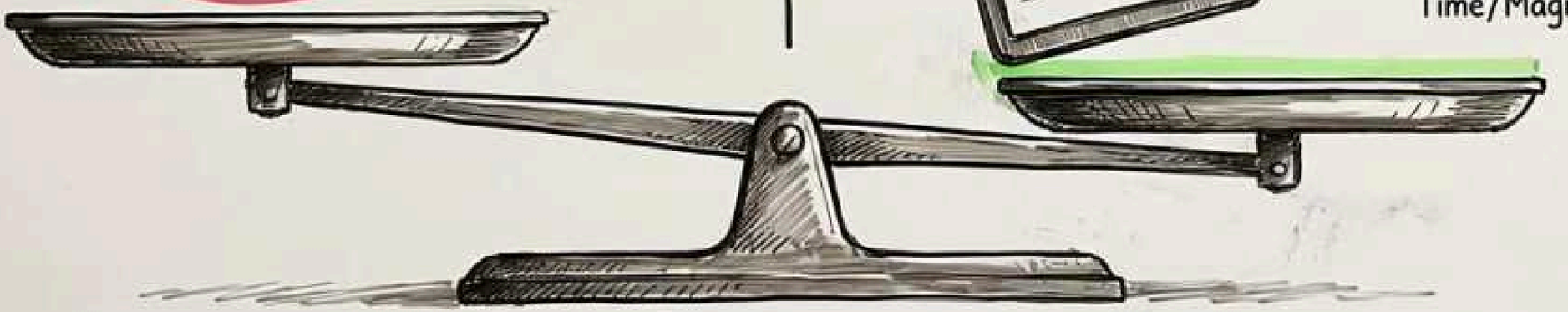


Forecasting & Action

Long-term probabilities can be estimated.
Actionable Steps: Build well, plan, warn.







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¶ 4.14

Volcanic Distribution

- **Definition:** Vents for magma, ash, and gas.
- **Locations:** Plate boundaries (75% in Pacific Ring of Fire).
- **Exceptions:** Ridges (Iceland), Hot spots (Hawaii).

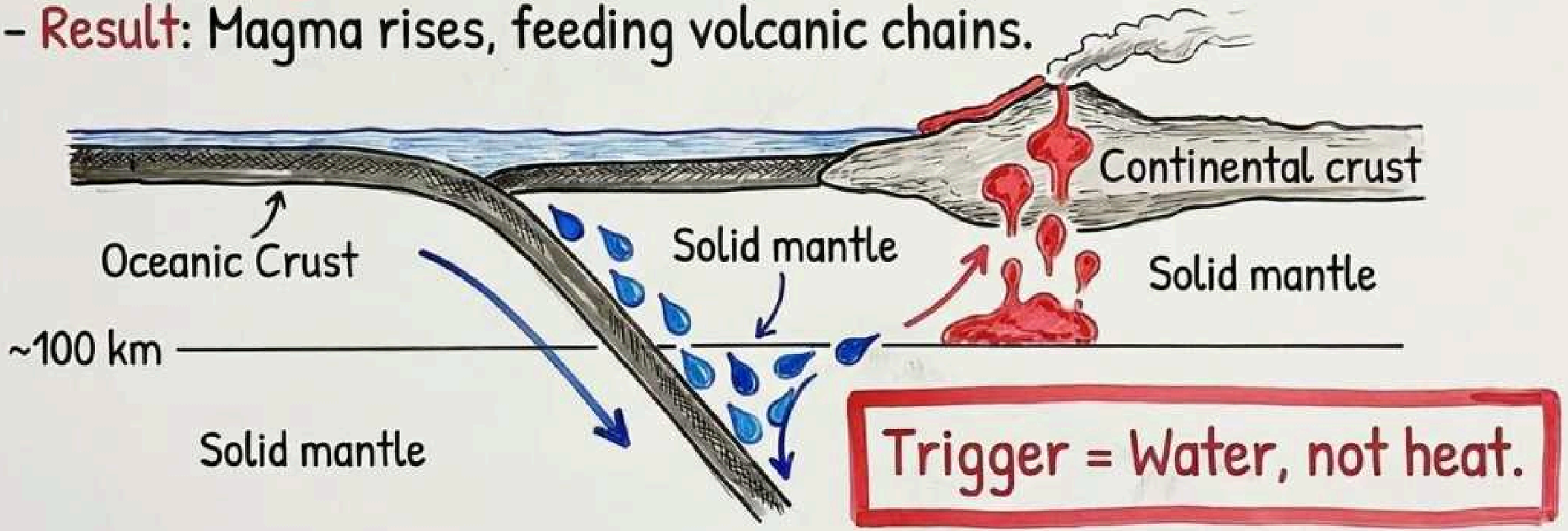


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¶ 4.15

Why Subduction Makes Magma

- **Mechanism**: Sinking plate carries water down in its minerals.
- **Depth**: ~100 km.
- **Flux Melting**: Water lowers the mantle's melting point.
- **Result**: Magma rises, feeding volcanic chains.



Trigger = Water, not heat.

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¶ 4.16

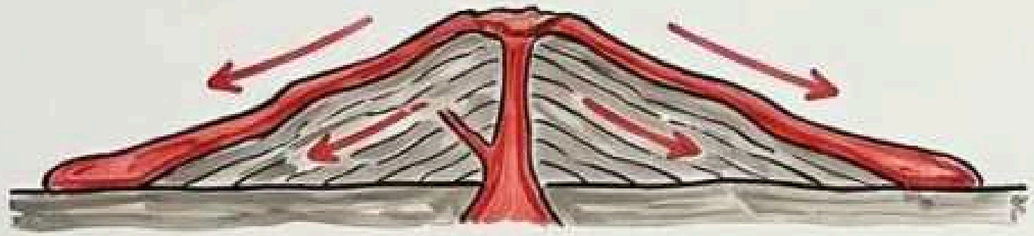
The Tale of Two Magmas

Basaltic Magma

Low silica, runny, gas escapes, gentle flow (Hawaiian shields)

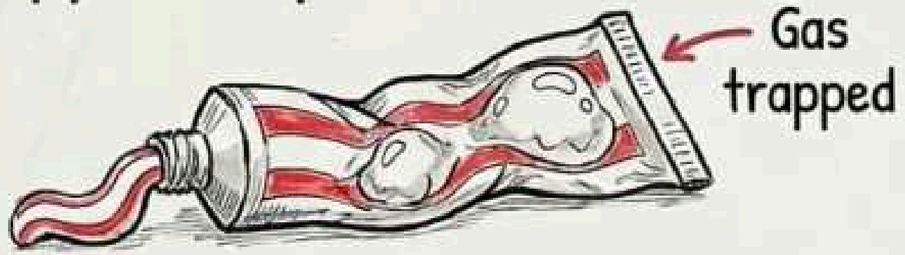


Shield Volcano

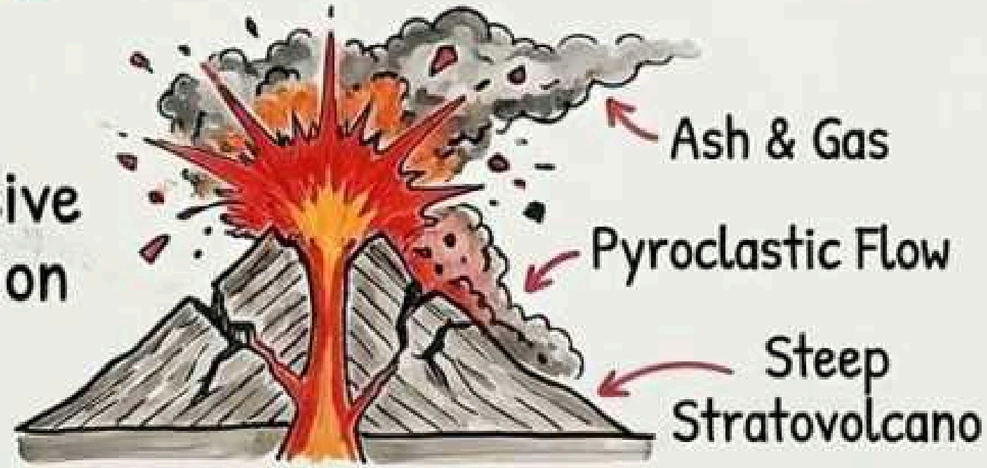


Rhyolitic Magma

High silica, thick paste, gas trapped, explosive



Explosive Eruption



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¶ 4.17

Three Common Volcano Profiles



Mauna Loa:
Wide, gentle slopes.

Mt. Fuji, St. Helens:
Steep, alternating lava/ ash, most dangerous.

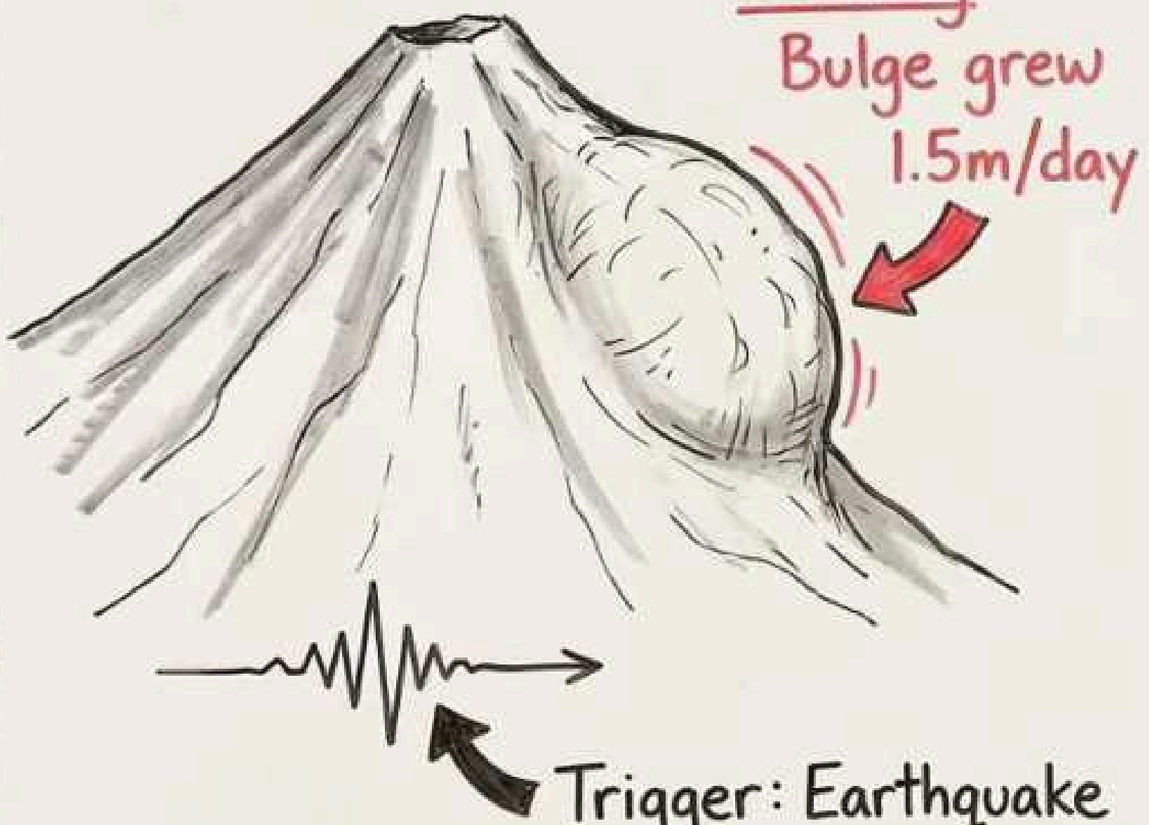
Small, steep fragment piles, erupt once.

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Case Study: Mount St. Helens (1980)

¶ 4.18

①



②



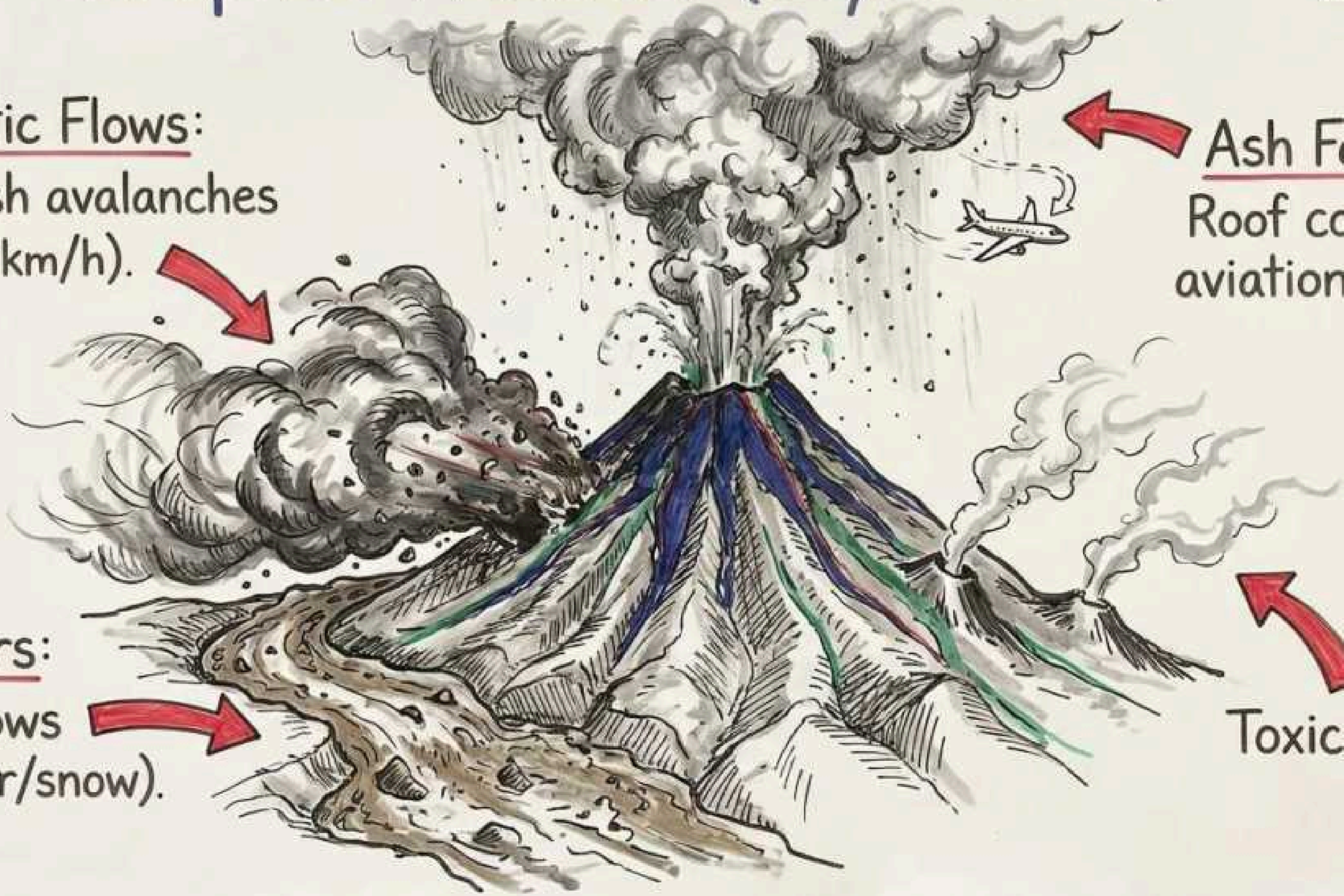
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Eruptive Products (Beyond Lava)

¶ 4.19

Pyroclastic Flows:
Hot gas/ash avalanches (>100 km/h).

Ash Falls:
Roof collapse, aviation hazard.



Lahars:
Mudflows (ash + water/snow).

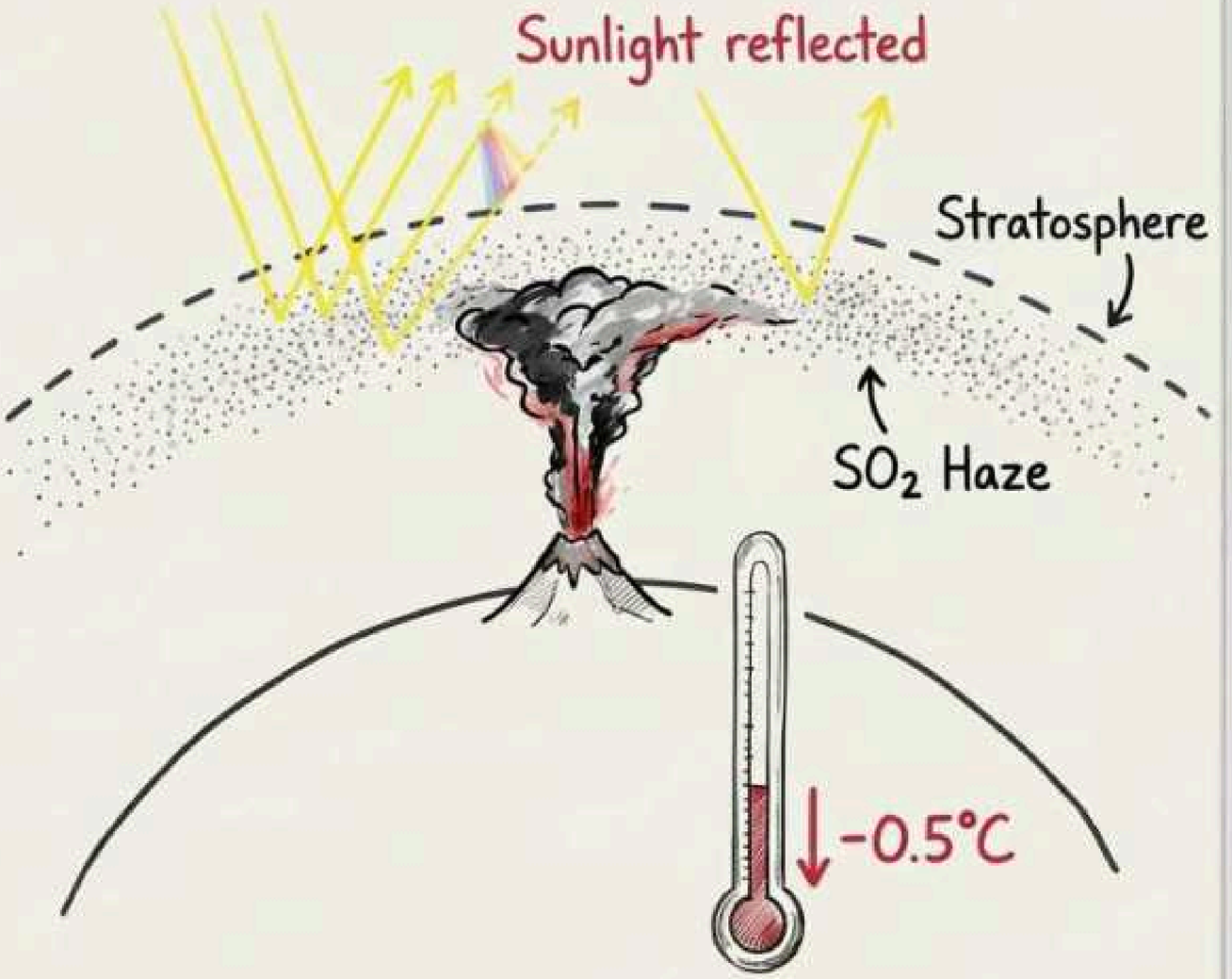
Toxic Gases.

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Global Cooling Effects

¶ 4.20

- Mt. Pinatubo (1991): threw 20M tons of Sulfur Dioxide into the stratosphere.
- Mechanism: SO_2 droplets reflect sunlight in stratosphere.
- Result: Global temp dropped ~0.5°C for a year.
- Tambora (1815): Caused the "Year Without a Summer."



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Test Your Understanding

¶ 4.21

Q1: A seismometer records a 45-second gap between the P and S waves. How far away is the earthquake?

Q2: If one earthquake is mag 8 and another is mag 7, how much more energy did the first release, and why are the two numbers not simply a ratio of 8 to 7?

(Recall Distance Math and Logarithmic Scales)

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Next Time: Lecture 5

¶ 4.22

- Moving to the Earth's surface.
- The slow work of shaping the land: Weathering, Rivers, Groundwater, Ice.



End of Lecture 4

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