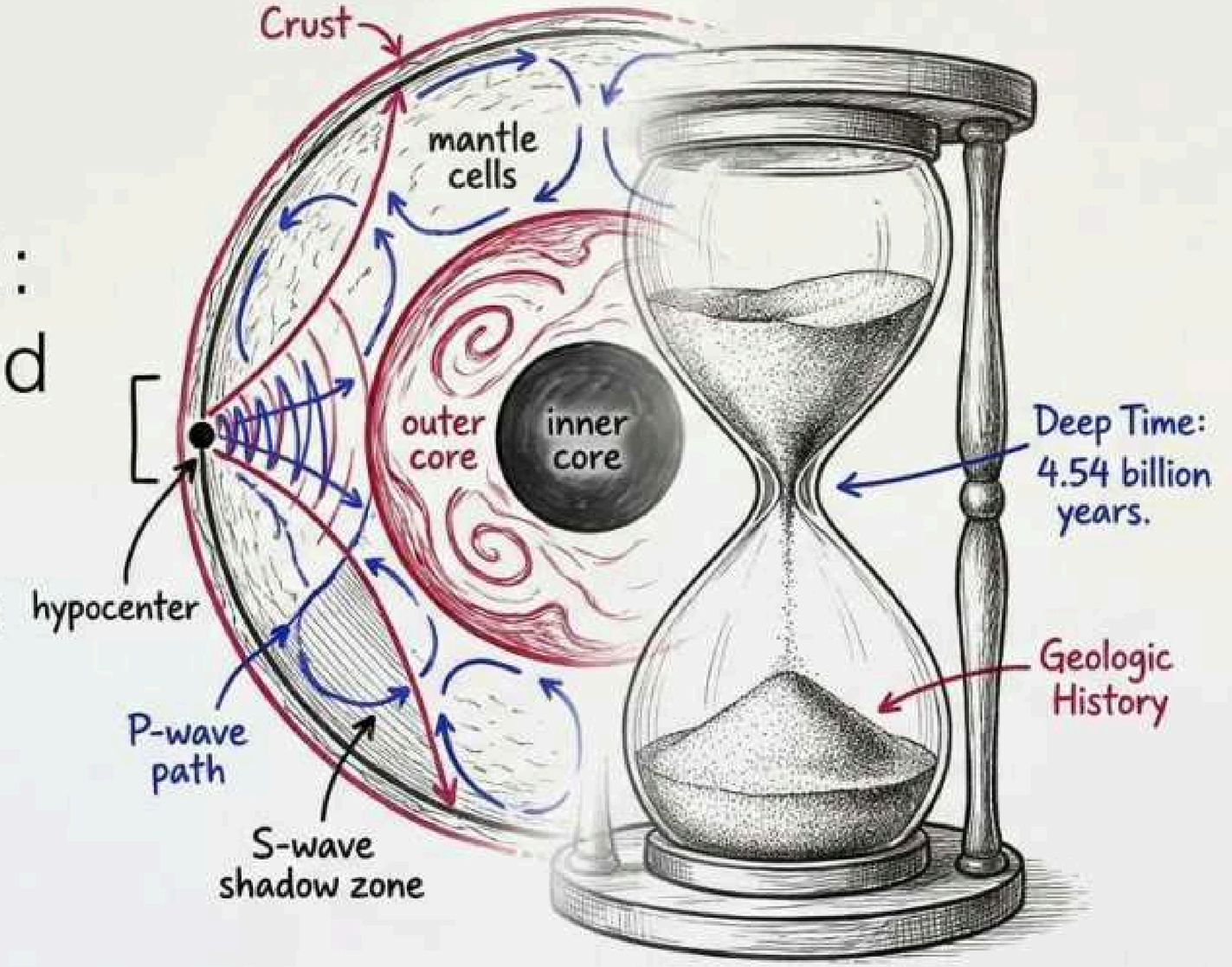
¶ 1.1

GEOL 101 B Lecture 1: The Layered Earth and Deep Time

At a glance — Seismic waves, the four layers of the Earth, radioactive dating, and the 4.54-billion-year history of the planet.

Welcome to Lecture 1.



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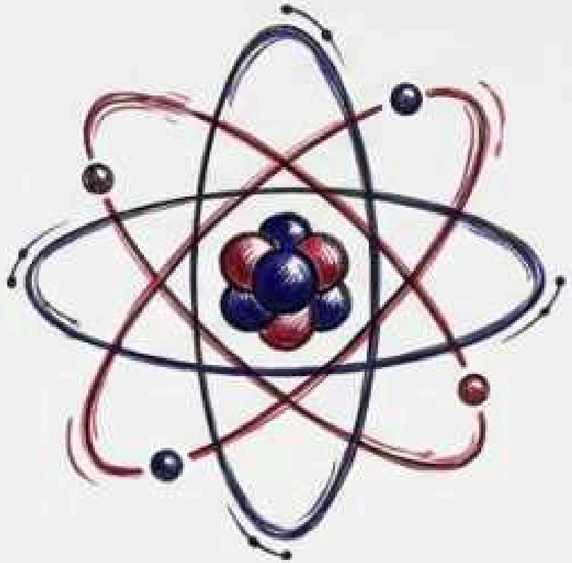
What is the Earth made of, deep down?

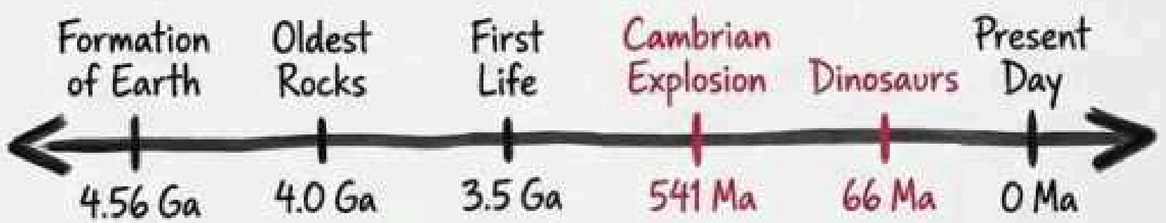


Read via earthquake waves

¶ 1.2

How old is it?

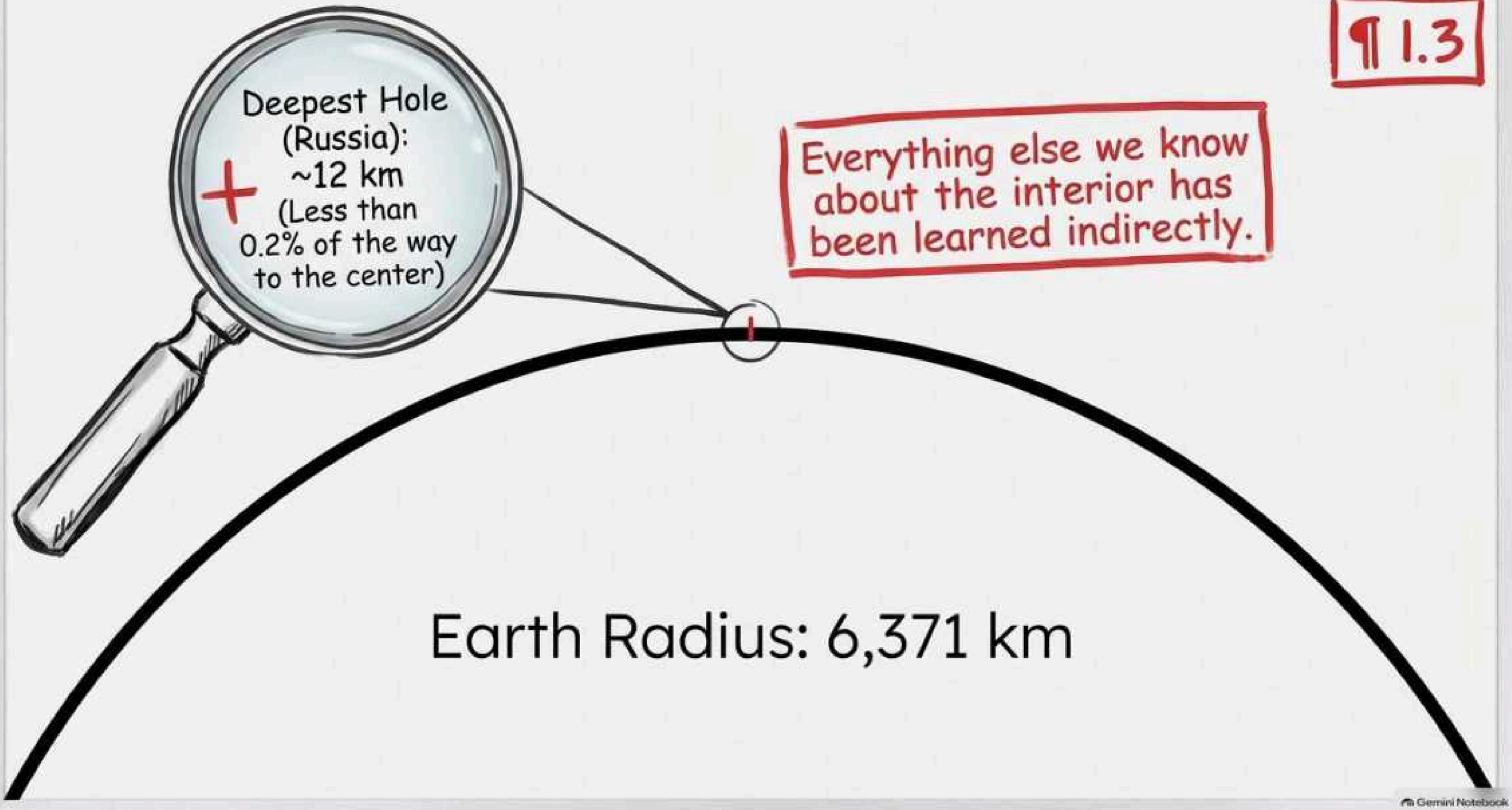




Measured via radioactive atoms

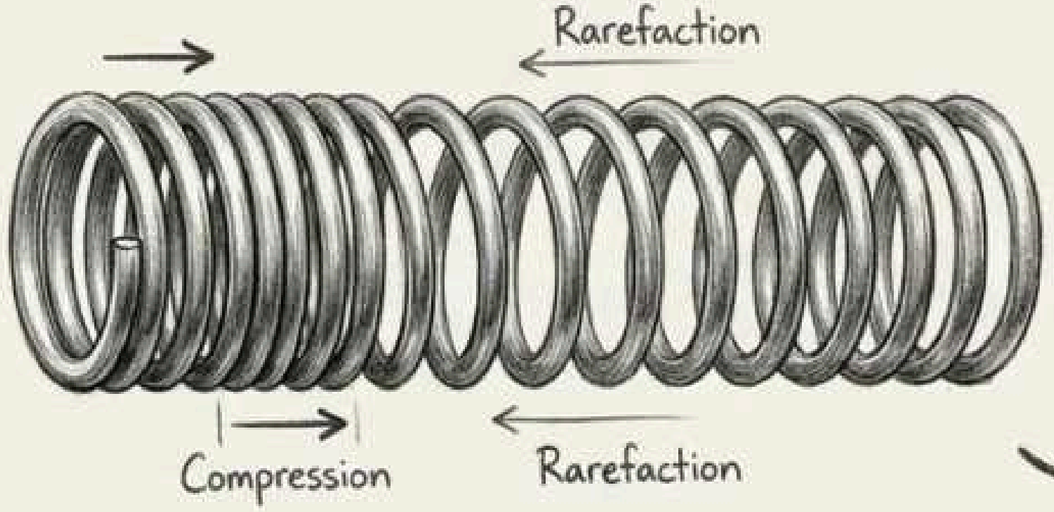
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¶ 1.3



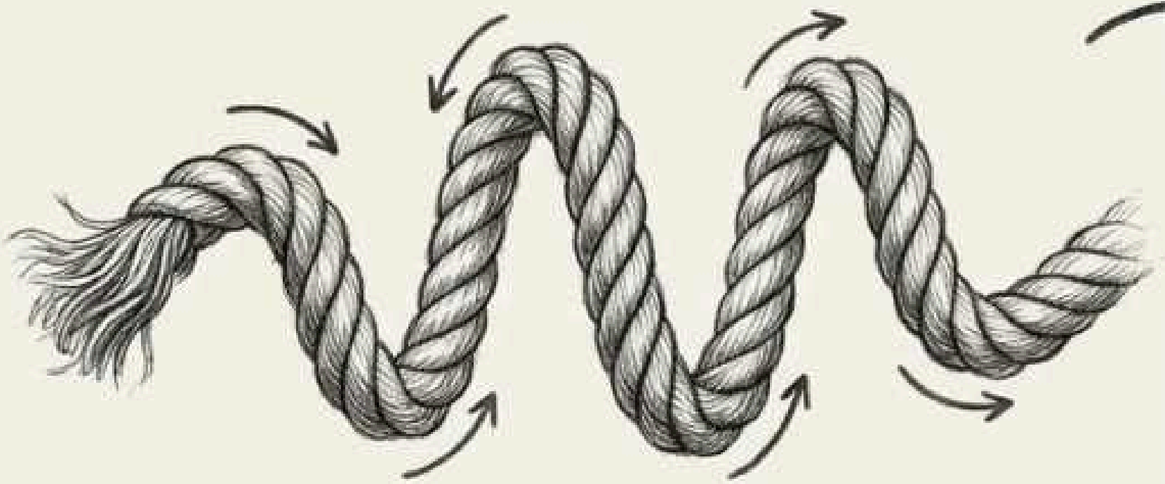
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¶ 1.4



P Waves (Compressional)

Travels through Solids & Liquids.

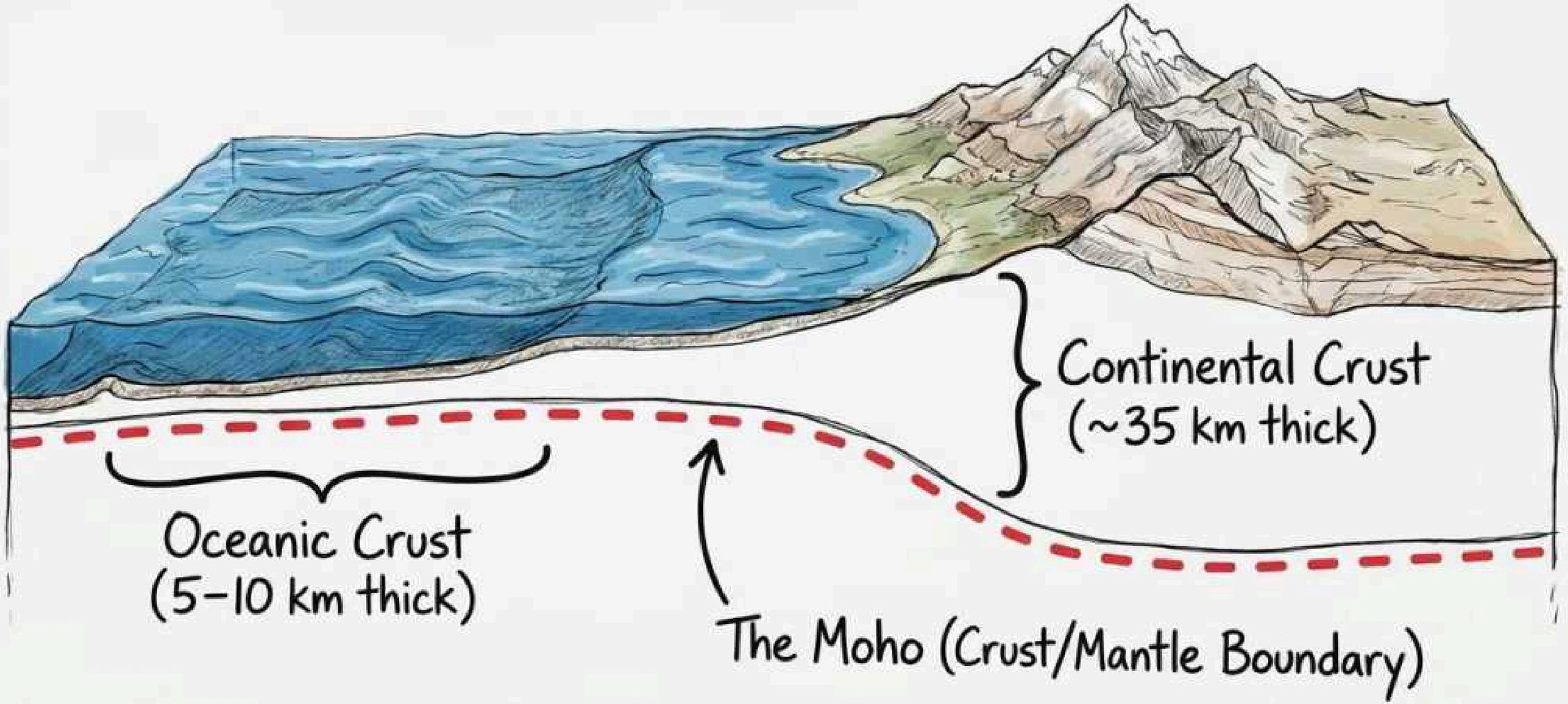


S Waves (Shear)

Travels through Solids **ONLY.**

1909: Andrija Mohorovičić discovers waves speed up at a certain depth.

¶ 1.5

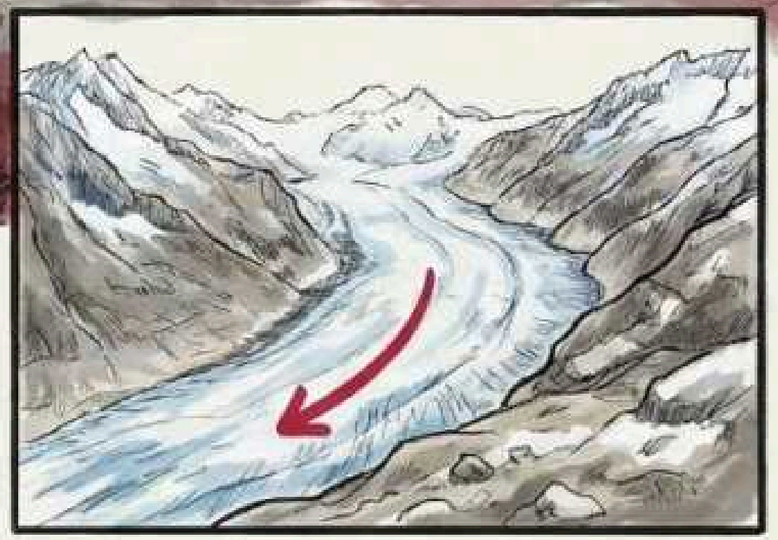


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¶1.6

The Mantle

- ~2,900 km thick (Makes up most of Earth's volume)
- State: Solid Rock



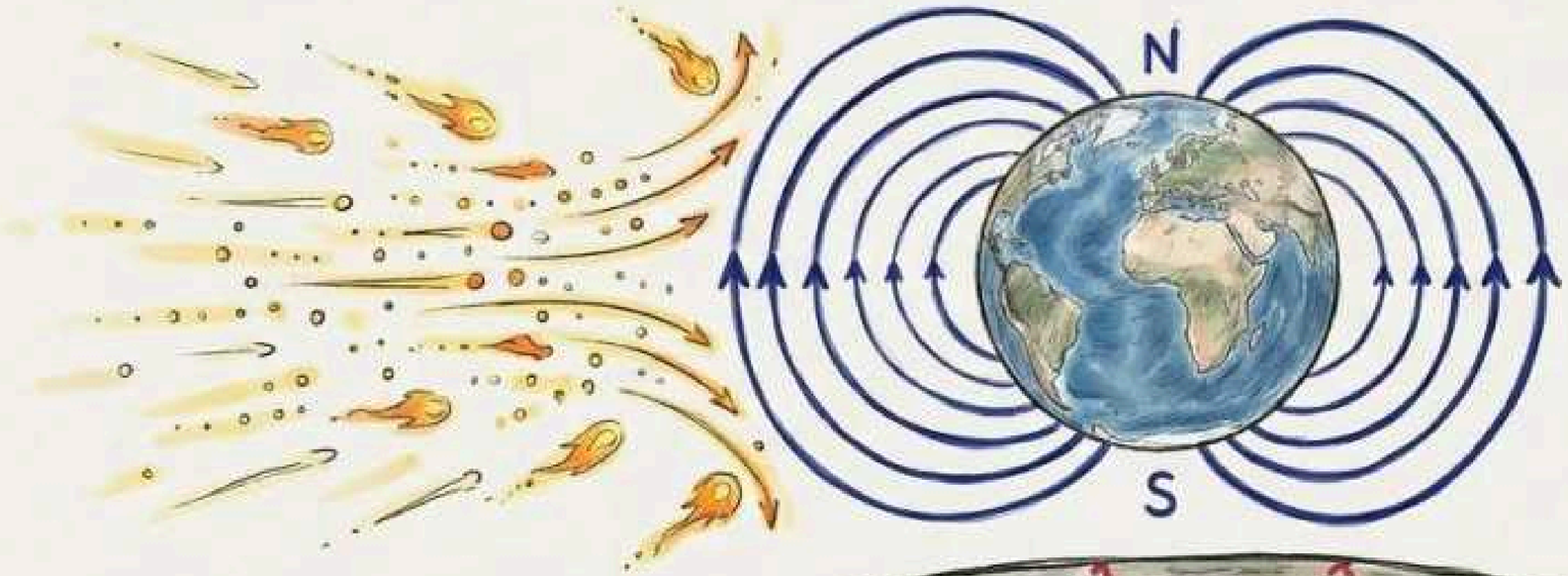
Mechanism:
Flows very slowly over millions of years (like cold honey or creeping glacier ice)

This slow flow drives everything in Lecture 3.

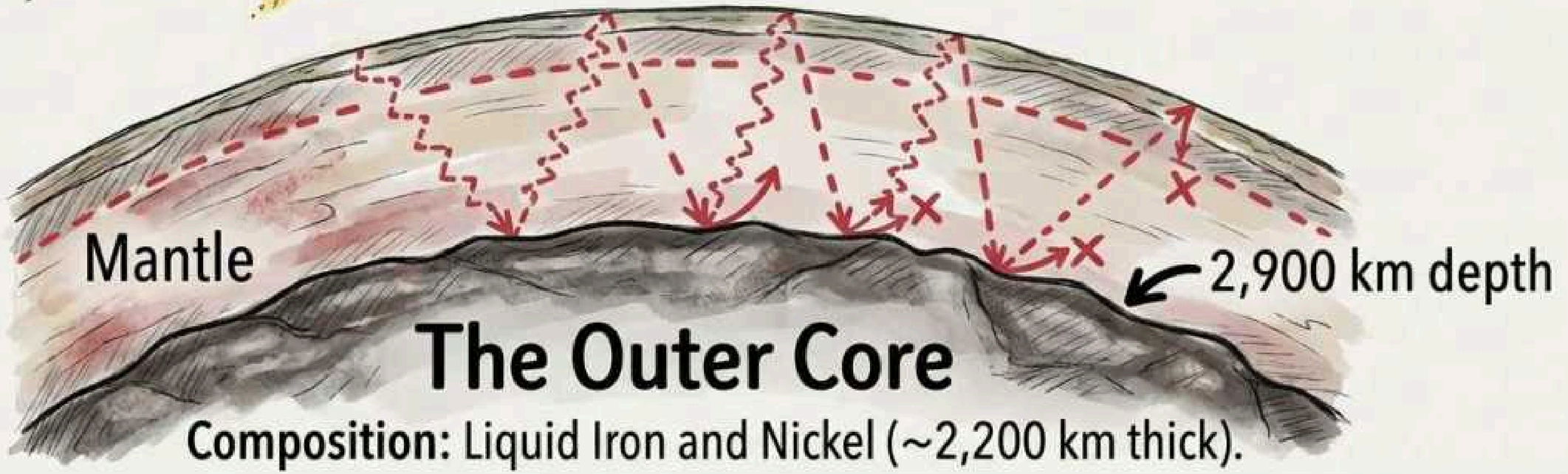
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1913: Beno Gutenberg notes S-waves vanish.

¶ 1.7



Global Effect: Slow churning generates Earth's magnetic field, shielding us from charged particles from the Sun.



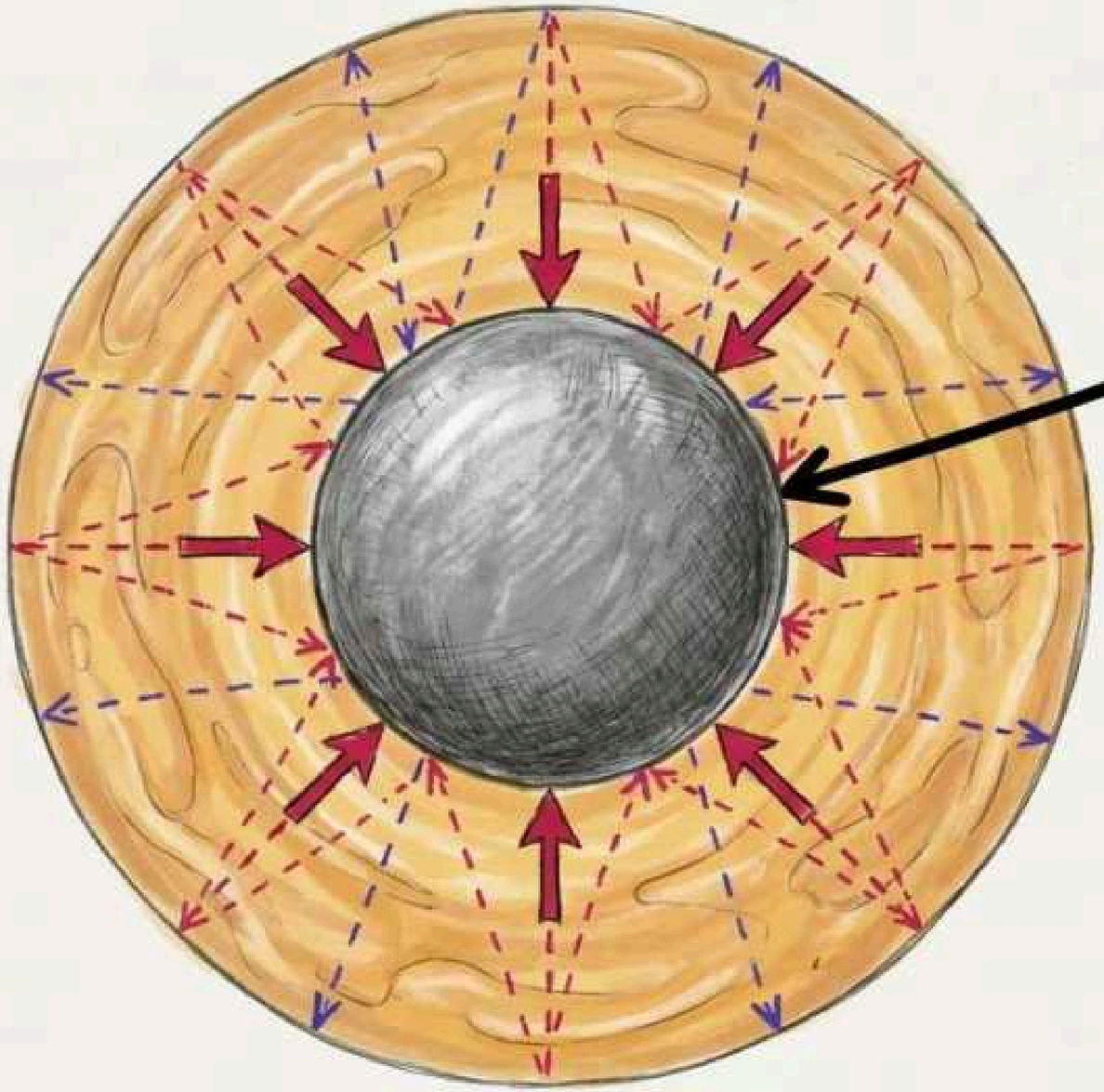
The Outer Core

Composition: Liquid Iron and Nickel (~2,200 km thick).

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1936: Inge Lehmann discovers faint bouncing waves.

¶ 1.8



The Inner Core

- Composition: Solid ball of Iron and Nickel (Radius: ~1,220 km)
- Conditions: 5,000 to 6,000 °C

Insight: Stays solid due to enormous pressure.

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¶ 1.9

$$\rho = \frac{m}{V}$$

Earth's Mass:
5.97×10^{24} kg

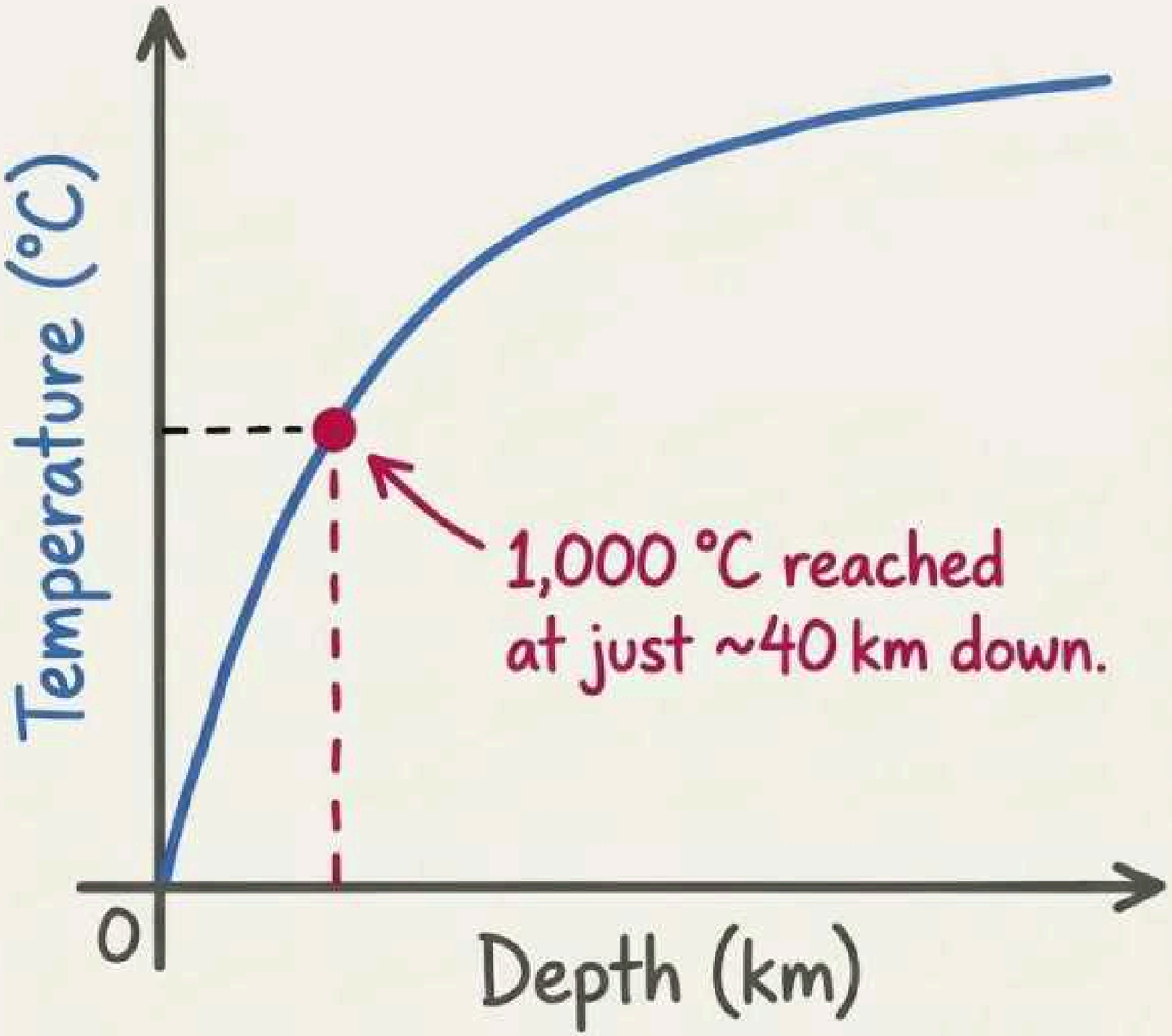
Surface Rock Density
= 2,700 kg/m³

Average Density = 5,500 kg/m³

The interior must be much denser → Iron Core confirmed.

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¶ 1.10



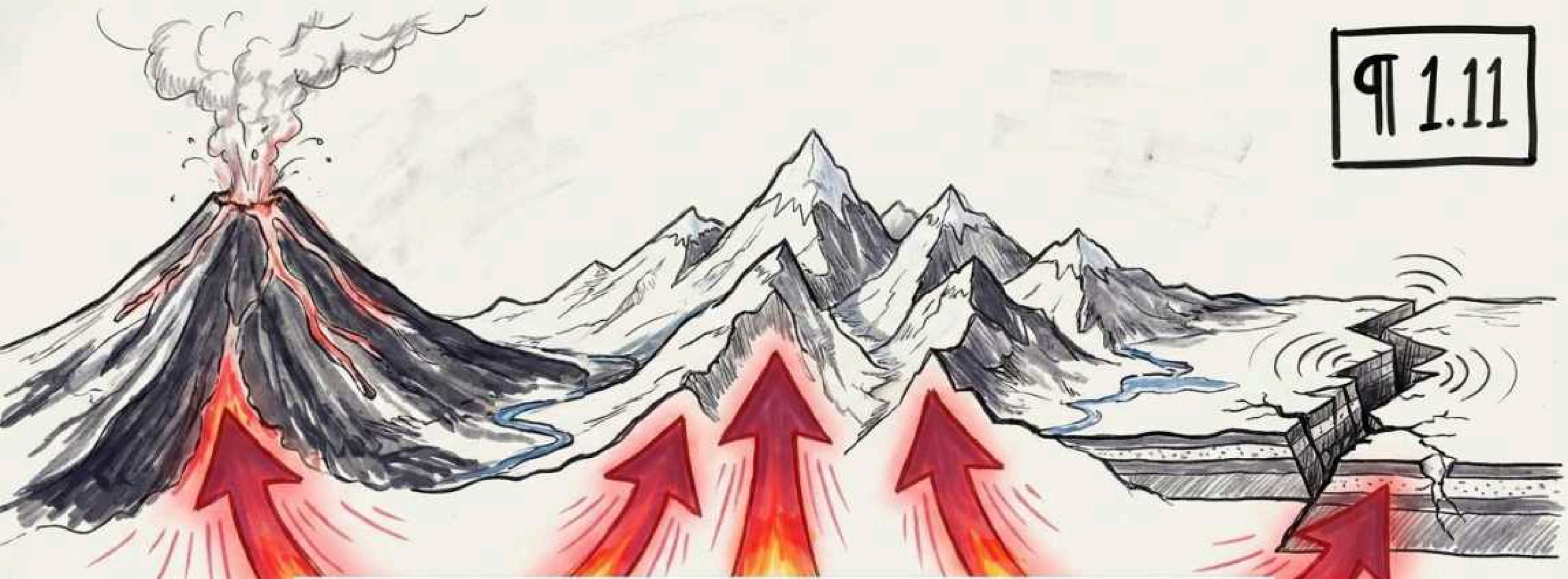
Surface climbing rate:
25 °C per km.

Heat Sources:

- 1. Leftover heat from the planet's formation.
- 2. Decay of radioactive atoms.

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¶ 1.11

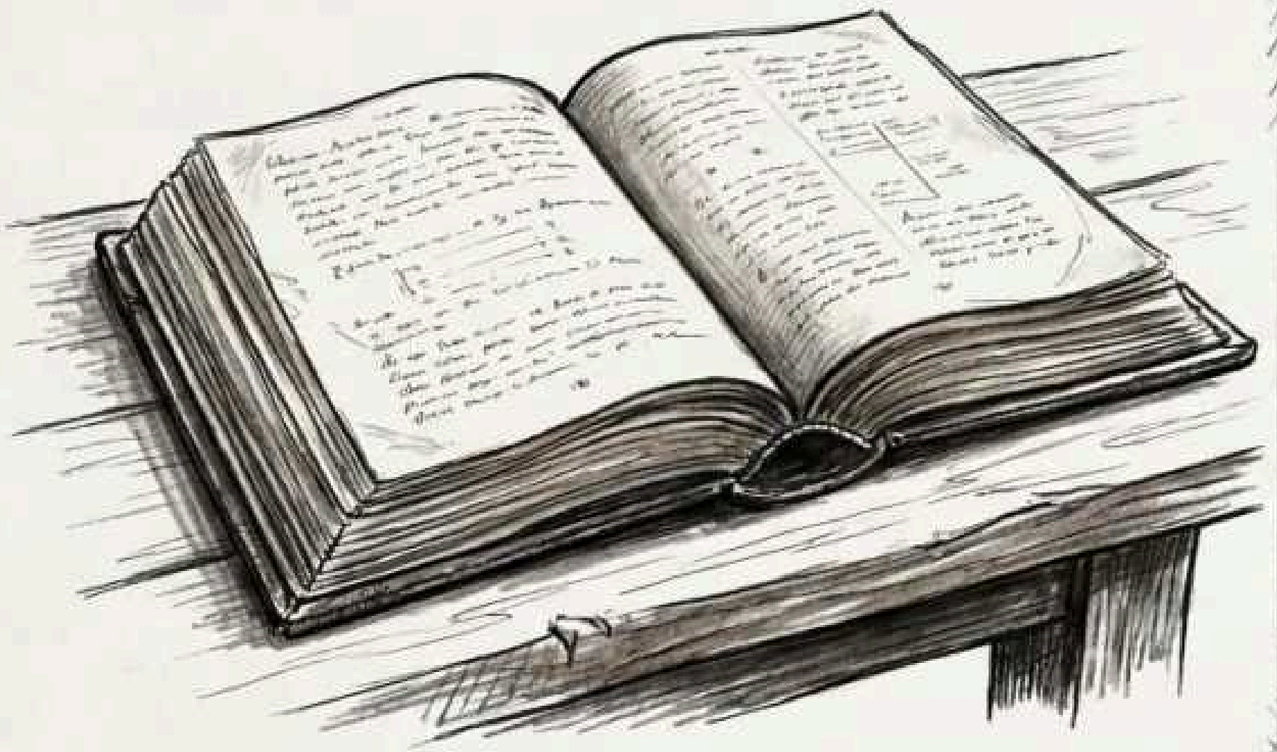


Core Concept: The Earth is a Heat Engine, still cooling after 4.5 billion years.

Insight: Every volcano, every mountain range, and every earthquake in this course is, in the end, a way for the planet to release heat.

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¶ 1.12



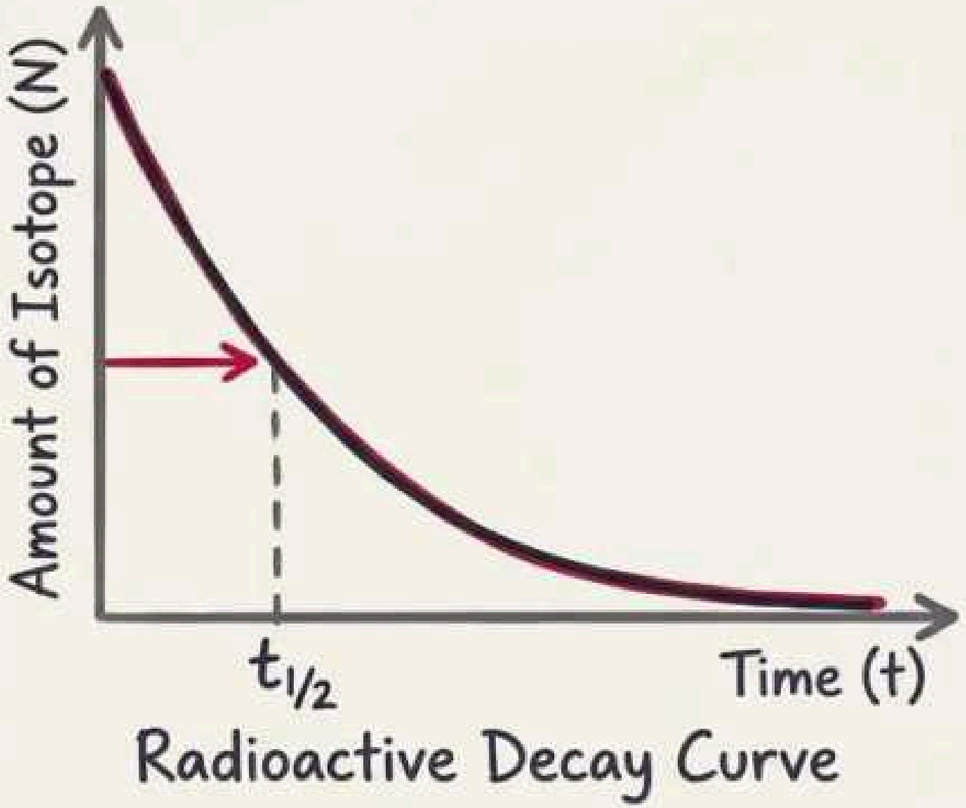
1650: Archbishop James Ussher added up Biblical ages → Creation → Creation in 4004 BC.



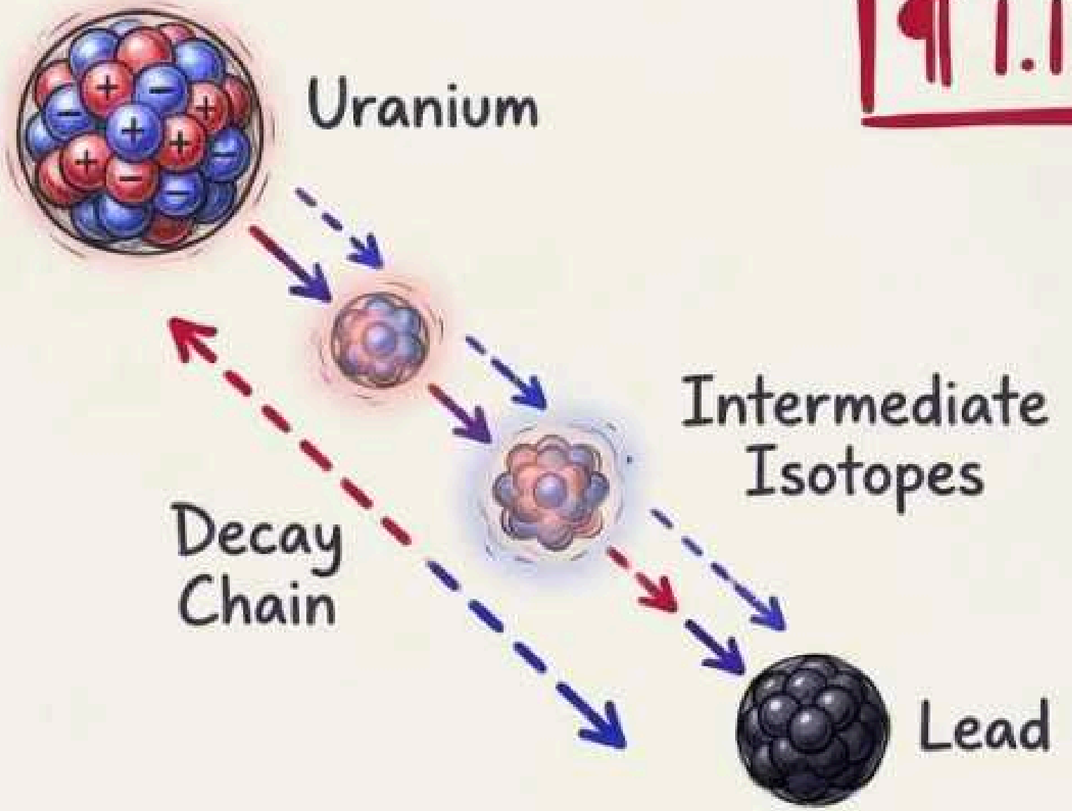
1800s Geologists: Observed rock layers that take far longer to form, but lacked a measuring clock.

Gemini Notebook

¶ 1.13



Radioactive Decay Curve



- **Mechanism:** Radioactive isotopes decay at a fixed rate, unaffected by heat or pressure.
- **Definition:** Half-life ($\mathbf{t_{1/2}}$): Time for half of a sample to decay.
- **Key Isotope:** Uranium-238 → Lead
- **Constant Rate:** $t_{1/2}$ = 4.47 Billion Years

Gemini Notebook

¶ 1.14

Scenario: A crystal retains 80% of its original U-238.



Equation:

$$\text{Age} = t_{1/2} \times \log_2\left(\frac{1}{\text{Remaining Fraction}}\right)$$

Calculation:

$$4.47 \text{ billion} \times \log_2\left(\frac{1}{0.8}\right)$$

Result: 4.47×0.322

$= 1.44$ billion years old.

Gemini Notebook

¶ 1.15



Isotope: Carbon-14 ($t_{1/2}$ = 5,730 years).
Used to date recent organic material.

Scenario: A bone retains 1/8th of its original C-14.

Logic Check: 1/8th remaining = exactly 3 half-lives passed.

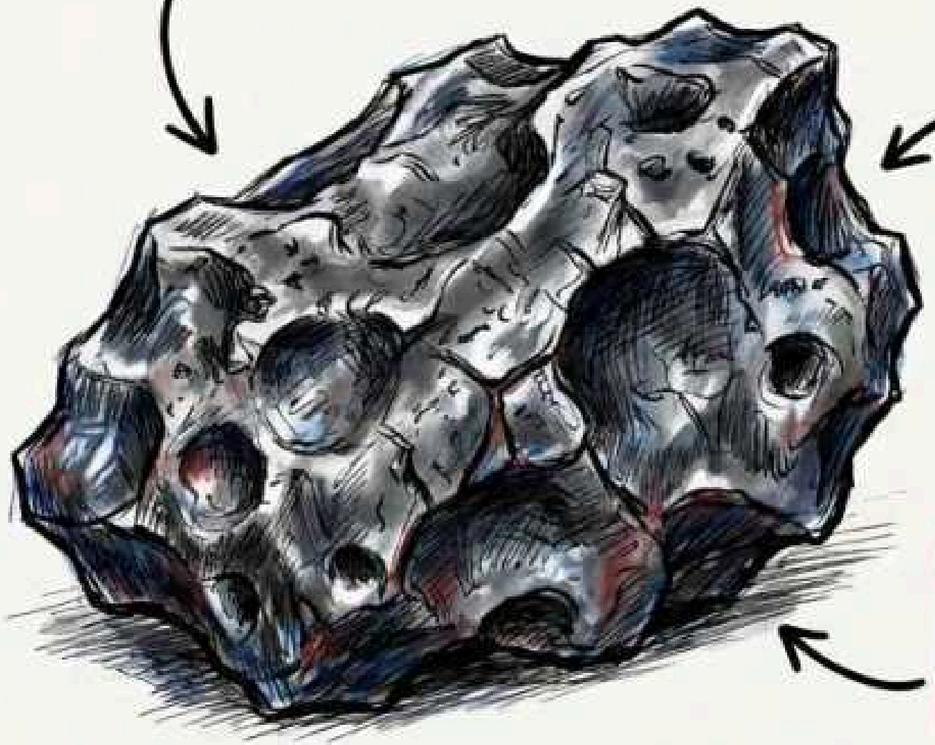
Math: 3 × 5,730 = 17,190 years (Places the animal in the last ice age).

Limitation: Fades beyond ~50,000 years (too little remains to measure).

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¶ 1.16





1953: **Clair Patterson** measures **lead isotopes** in **meteorite fragments** (leftovers from solar system formation).

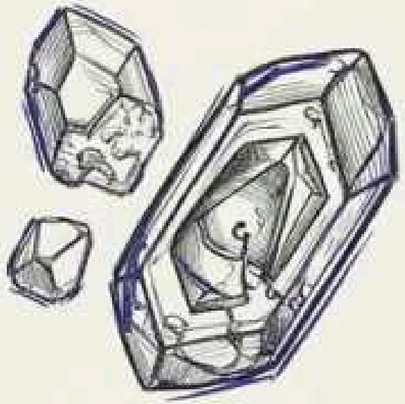
Patterson's Result: **~4.55 Billion Years**

Modern Accepted Age: 4.54 Billion Years (with an uncertainty of about 1%)

Gemini Notebook

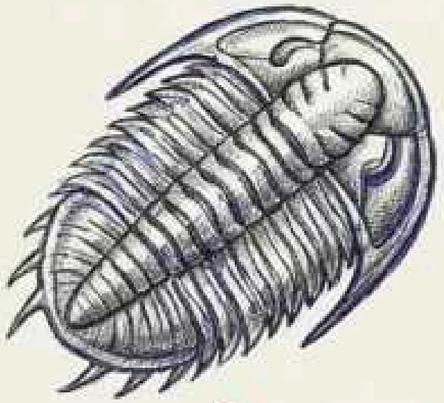
¶ 1.17

4.4 Billion:
Oldest tiny
Zircon crystals



4.0 Billion:
Oldest intact
rocks

539 Million:
Cambrian period begins
(abundant shelled animals)



66 Million:
Dinosaur extinction



4.54 Billion
Years Ago

Tiny, resilient
time capsules

Acasta Gneiss, Canada
– first continental crust?

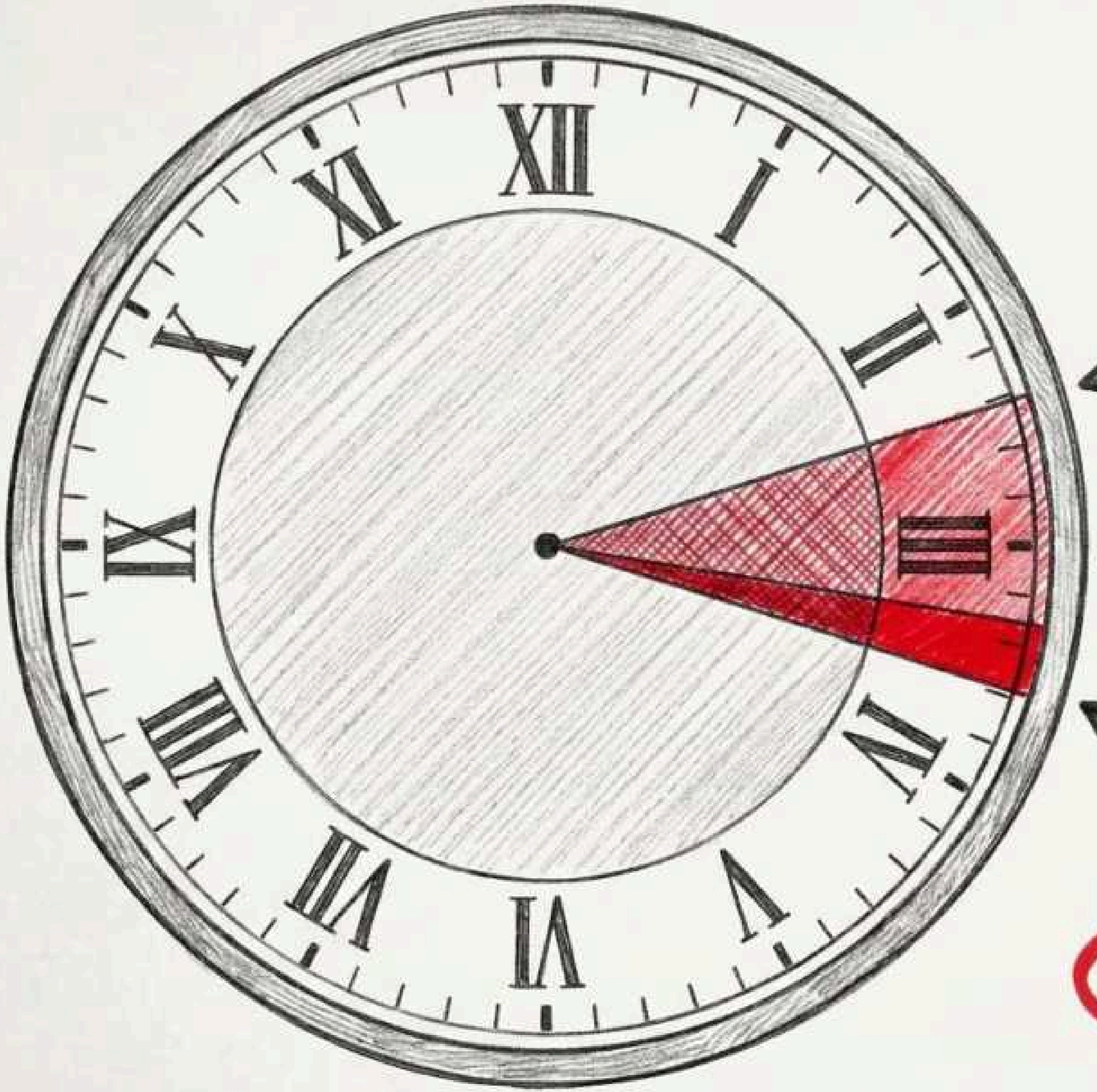
Explosion of life
with hard parts

K-Pg
Boundary
event

Present
Day

Gemini Notebook

¶ 1.18

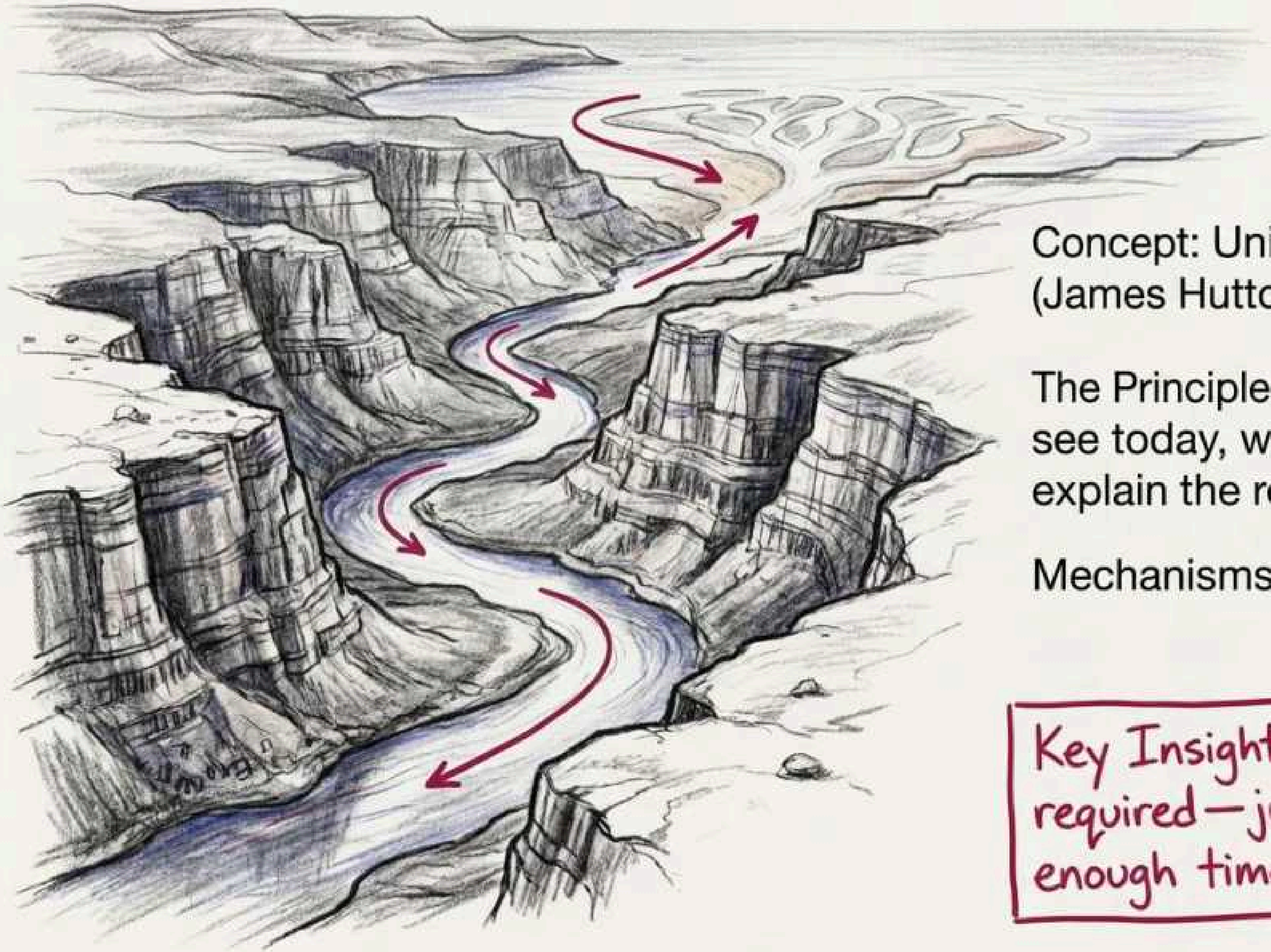


Scale: 1 Second = ~52,000 years.

- 21:00 (9 PM): Cambrian begins.
- 23:39 (21 mins to midnight): Dinosaurs vanish.
- 23:59:54 (Last 6 seconds): Homo sapiens appears.
- **< 0.1 seconds: All of written human history.**

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¶ 1.19



Concept: Uniformitarianism
(James Hutton, 1788 & Charles Lyell)

The Principle: The slow processes we see today, working over vast time, explain the rocks.

Mechanisms: Rivers cut canyons.
Seas deposit sand.

Key Insight: No magic events required—just slow change, given enough time, does the work.

Gemini Notebook

¶1.20



- Event: Mars-sized body impact.
- Timing: ~4.5 billion years ago.
- Evidence: Apollo astronaut lunar rocks date from 3 to 4.4 billion years ago.
- Conclusion: The young Earth was heavily bombarded and completely molten; its very first crust has long since been recycled.

Gemini Notebook

¶ 1.21

Problem: Suppose a new rock contains a mineral with one quarter (1/4) of its original U-238 left.

Question 1: How many half-lives have passed? ☐

Question 2: How old is the rock? ☐

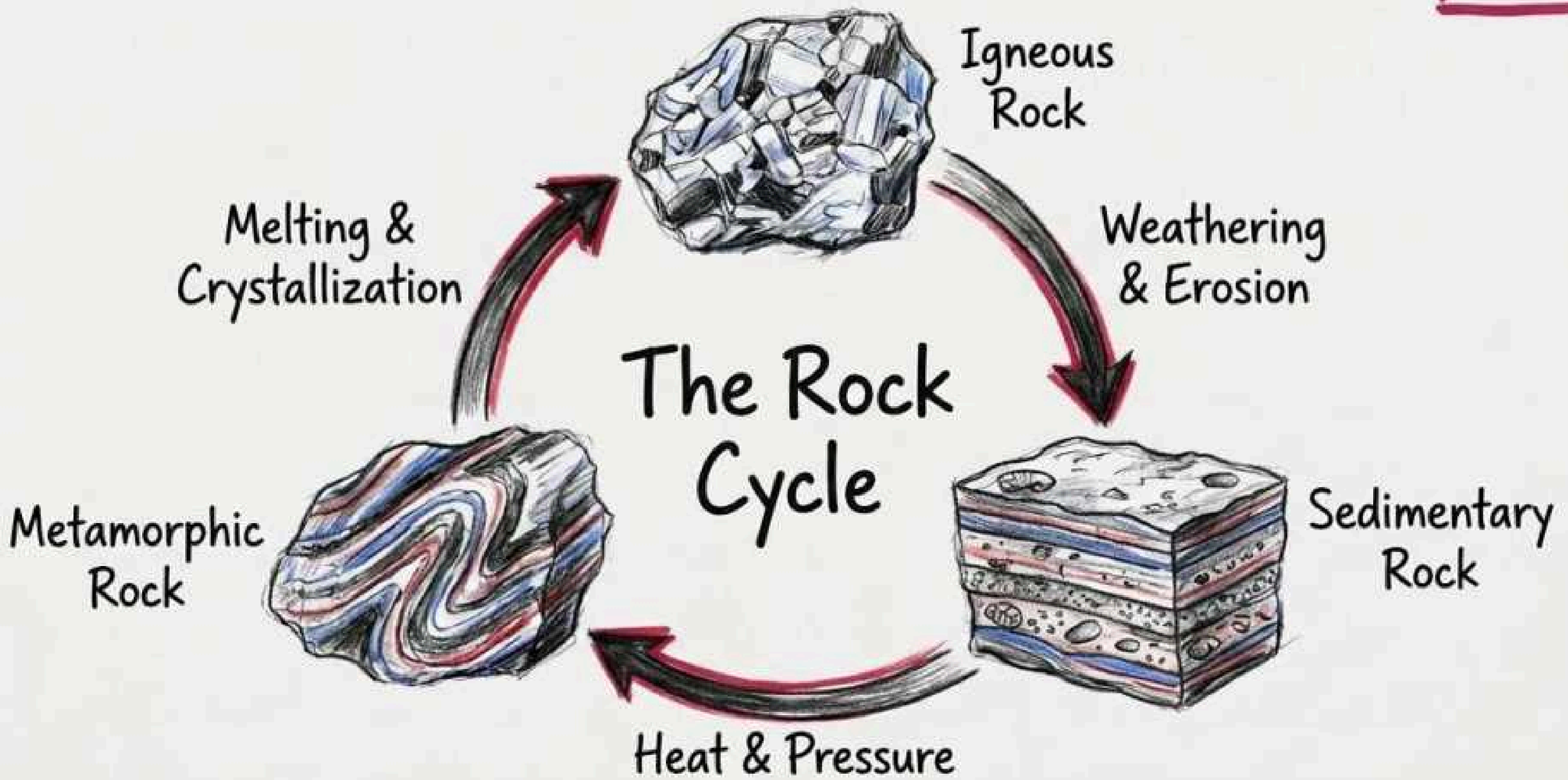
Question 3: What assumption is made about the crystal's starting conditions, and how might a geologist test it? ☐

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Preview of Lecture 2

¶ 1.22

Leaving the deep interior, we will begin handling the material itself.



Upcoming Topics: Minerals, the three major families of rock, and the Rock Cycle that links them all.

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