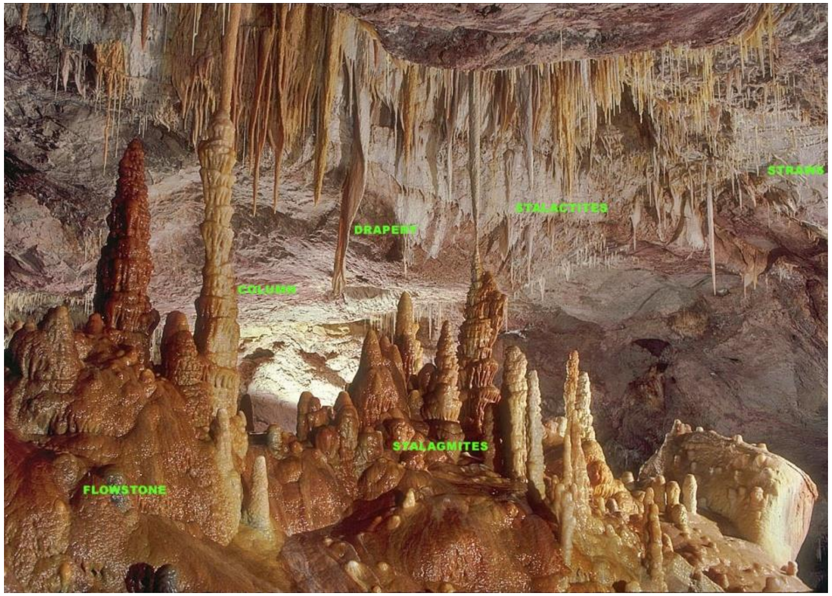
IDC 203: INTRODUCTION TO EARTH SCIENCES



Geology literally means "study of the Earth."

Physical geology examines the materials and processes of the Earth.

Historical geology examines the origin and evolution of our planet through time.

• Geology is an evolving science - the theory of plate tectonics was just accepted in the 1960's.

• Plate tectonics is the unifying theory in geology.

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•Although geologists treat it as a law - plate tectonics is still and will likely remain a theory…

Outline

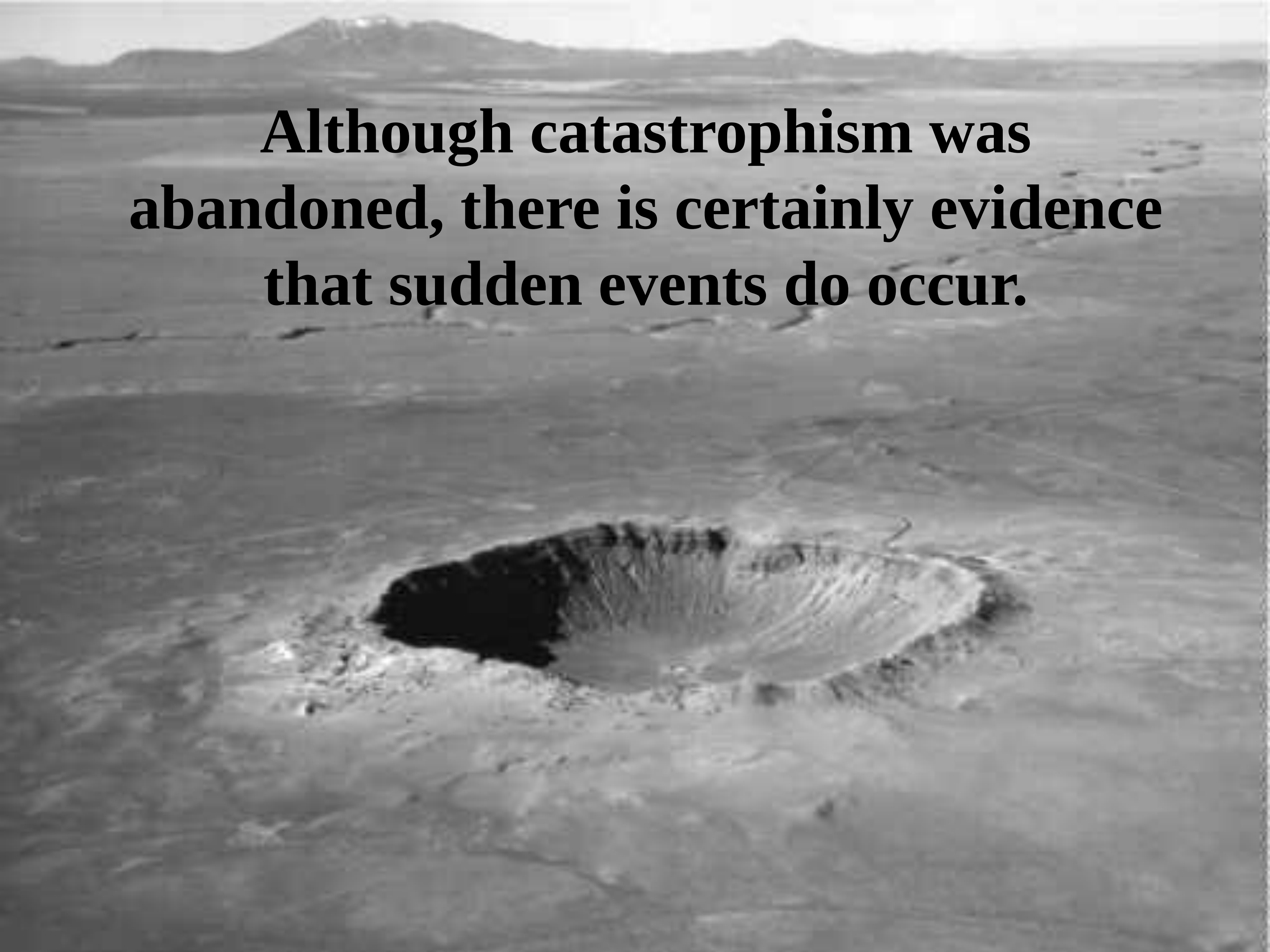
- **History/principles of geology**
- **Geological time scale**
- **Interior of earth**

History of Early Geology

Catastrophism (James Ussher, mid 1600s) - He interpreted the Bible to determine that the Earth was created at 4004 B.C. This was generally accepted by both the scientific and religious communities. Subsequent workers then developed the notion of catastrophism, which held that the Earth's landforms were formed over very short periods of time.

Uniformitarianism (James Hutton, late 1700s) - He proposed that the same processes that are at work today were at work in the past. Summarized by "The present is the key to the past." Hutton, not constrained by the notion of a very young planet, recognized that time is the critical element to the formation of common geologic structures. Uniformitarianism is a basic foundation of modern geology.

Although catastrophism was abandoned, there is certainly evidence that sudden events do occur.



Geologic Time

Relative Dating: Putting geologic events into proper order (oldest to youngest), but without absolute ages. We use a number of principles and laws to do this:

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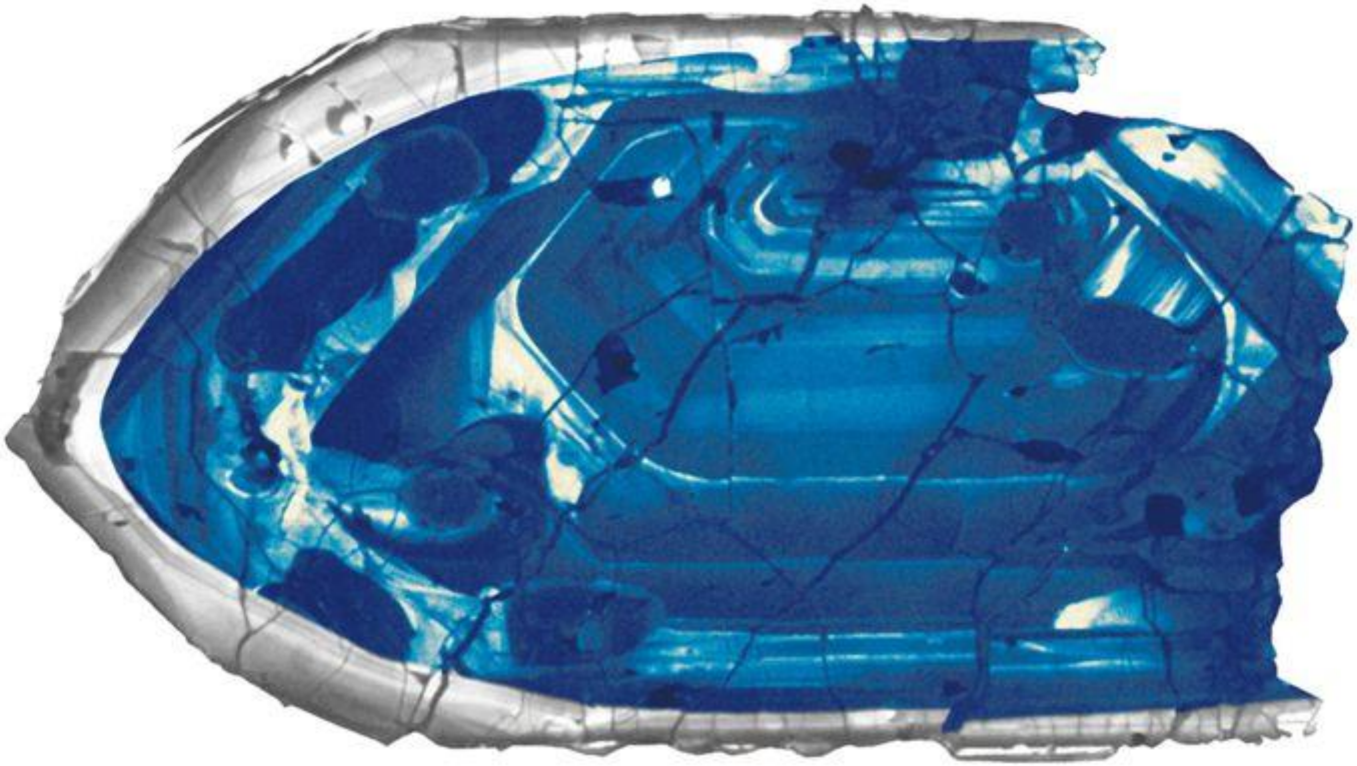
Geologic Time

Absolute (Radiometric) Dating: Using radioactive decay of elements to determine the absolute age of rocks. This is done using igneous and metamorphic rocks.

Parent	Decay Product	Half-Life (billion years)
Aluminum-26	Magnesium-26	0.00072 (720,000 years)
Uranium-235	Lead-207	0.71
Potassium-40	Argon-40	1.3
Uranium-238	Lead-206	4.5
Thorium-232	Lead-208	14
Rubidium-87	Strontium-87	47
Samarium-147	Neodymium-147	106

AGE OF EARTH



Geologic Time

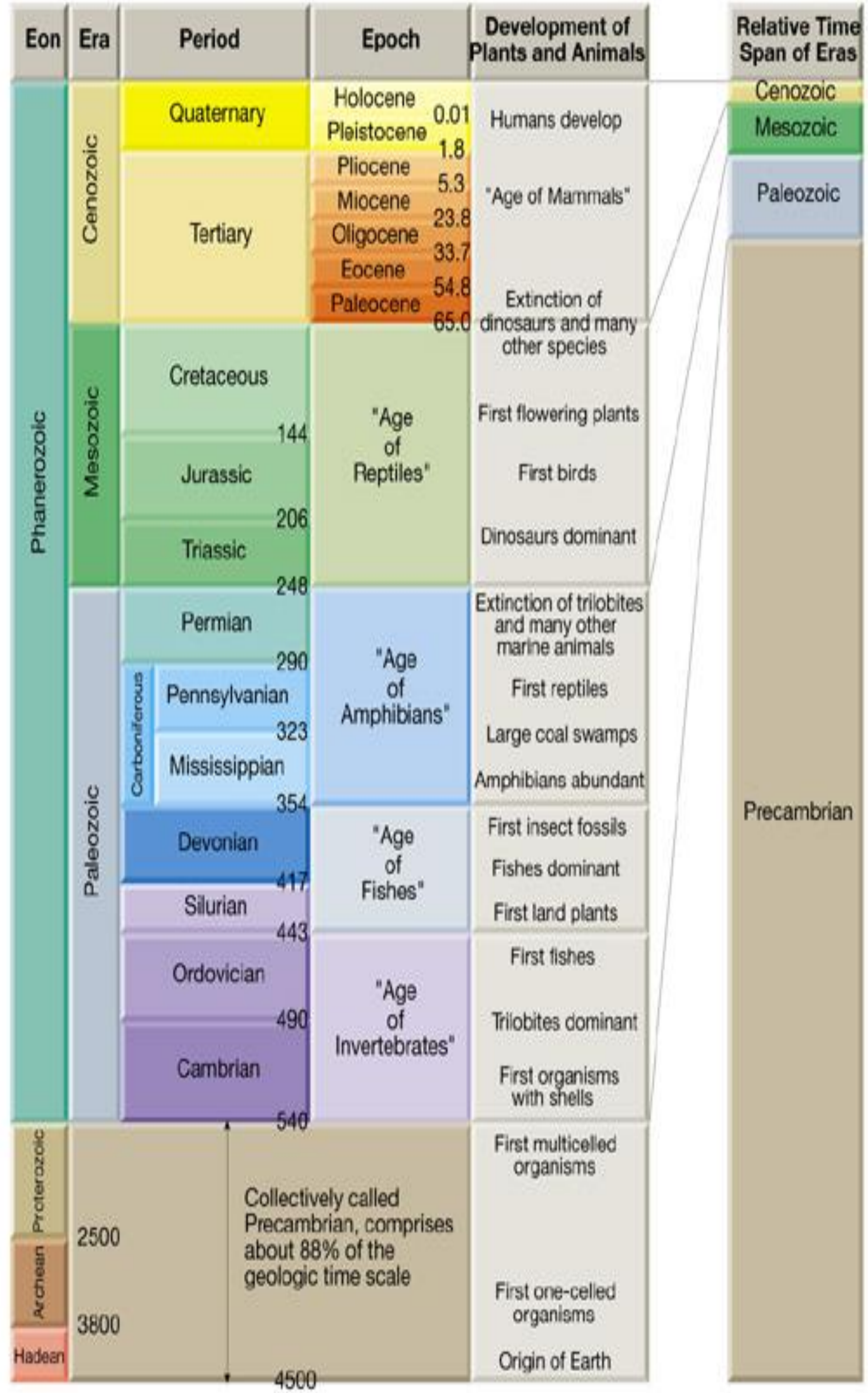
• The concept of geologic time is new (staggering) to many nongeologists.

• The current estimate is that the Earth is ~4,600,000,000 (4.6 billion) years old.

• As humans we have a hard time understanding the amount of time required for geologic events.

• We have a good idea of how long a century is. One thousand centuries is only 100,000 years. That huge amount of time is only 0.002% of the age of the Earth!

• An appreciation for the magnitude of geologic time is important because many processes are very gradual.



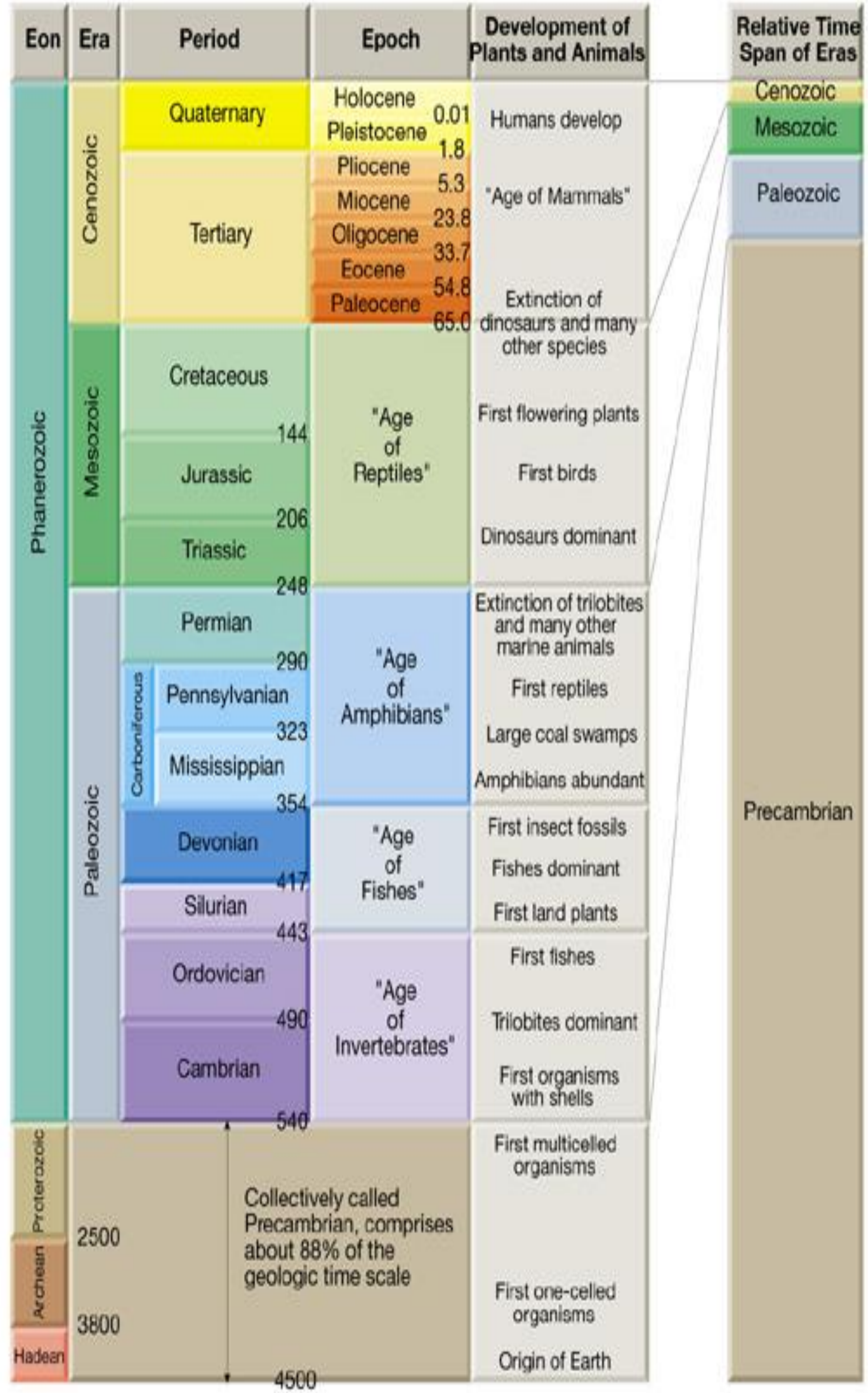
• Geologic time is divided into different types of units.

• Note that each Eon, Era or Period represents a different amount of time. For example, the Cambrian period encompasses ~65 million years whereas the Silurian period is only ~30 million years old.

• The change in periods is related to the changing character of life on Earth and other changes in environment.

• The beginning of the Phanerozoic represents the explosion of life.

• The time before the Phanerozoic is commonly referred to as the PreCambrian and represents over 4 billion years of time. The Phanerozoic eon (abundant life) represents only the



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SCIENCE

Extraterrestrial Cause for the Cretaceous-Tertiary Extinction

Experimental results and theoretical interpretation

Luis W. Alvarez, Walter Alvarez, Frank Asaro, Helen V. Michel

In the 570-million-year period for

microscopic floating animals and plants:

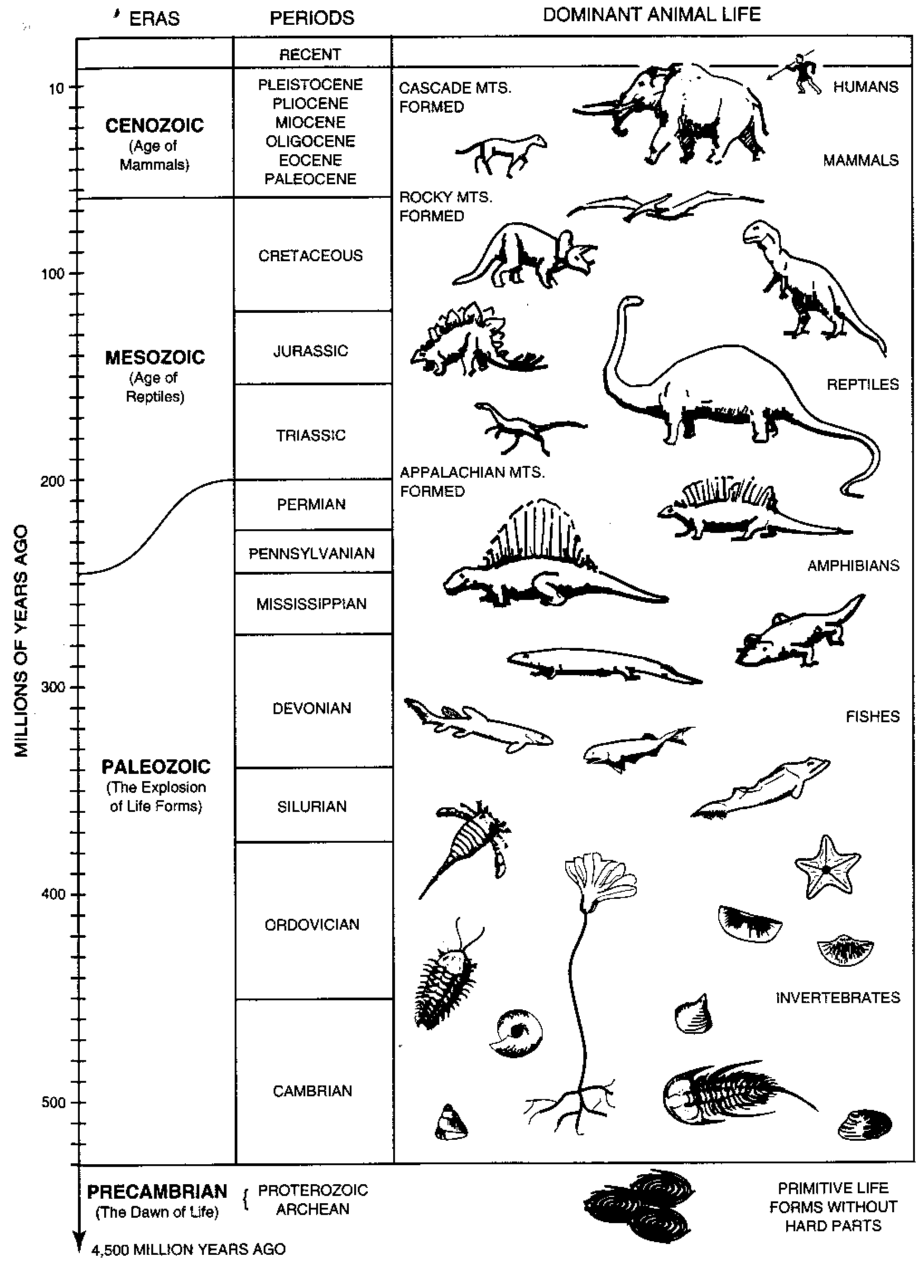
extinctions (*3*, *4*), and two recent meetings on the topic (*5*, *6*) produced no sign of a consensus. Suggested causes include gradual or rapid changes in oceanographic, atmospheric, or climatic conditions (*7*) due to a random (*8*) or a cyclical (*9*) coincidence of causative factors; a magnetic reversal (*10*); a nearby supernova (*11*); and the flooding of the ocean surface by fresh water from a postulated arctic lake (*12*).

A major obstacle to determining the cause of the extinction is that virtually all the available information on events at the time of the crisis deals with biological changes seen in the paleontological record and is therefore inherently indirect. Little physical evidence is available, and it also is indirect. This includes variations in stable oxygen and carbon isotop-

- Principle of Uniformitarianism
  - Major assumption in geology
  - Events in the past occurred the same way that they are occurring today. Examples Include:
    - Weathering/erosion
    - Deposition
    - Volcanism
    - Plate tectonics

Geologic Time

Geologists have divided Earth's history into time units based on the fossil record



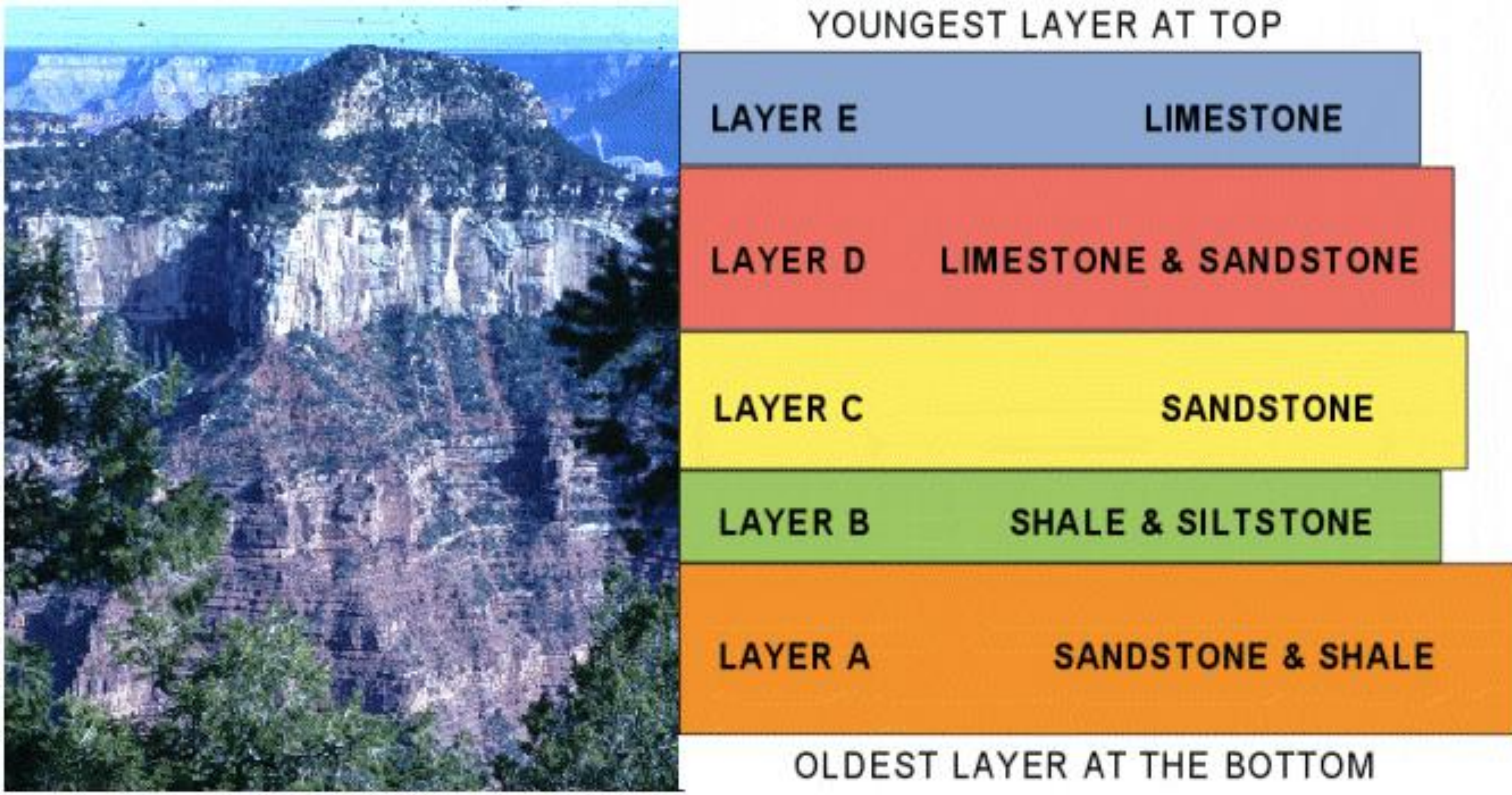
Geologic Time

- A study of the fossil record shows
  - A great variety of plants, animals, and simpler life forms have lived on Earth in the past
  - That life forms have evolved through time
  - Most life forms of the geologic past have become extinct

Law of Superposition

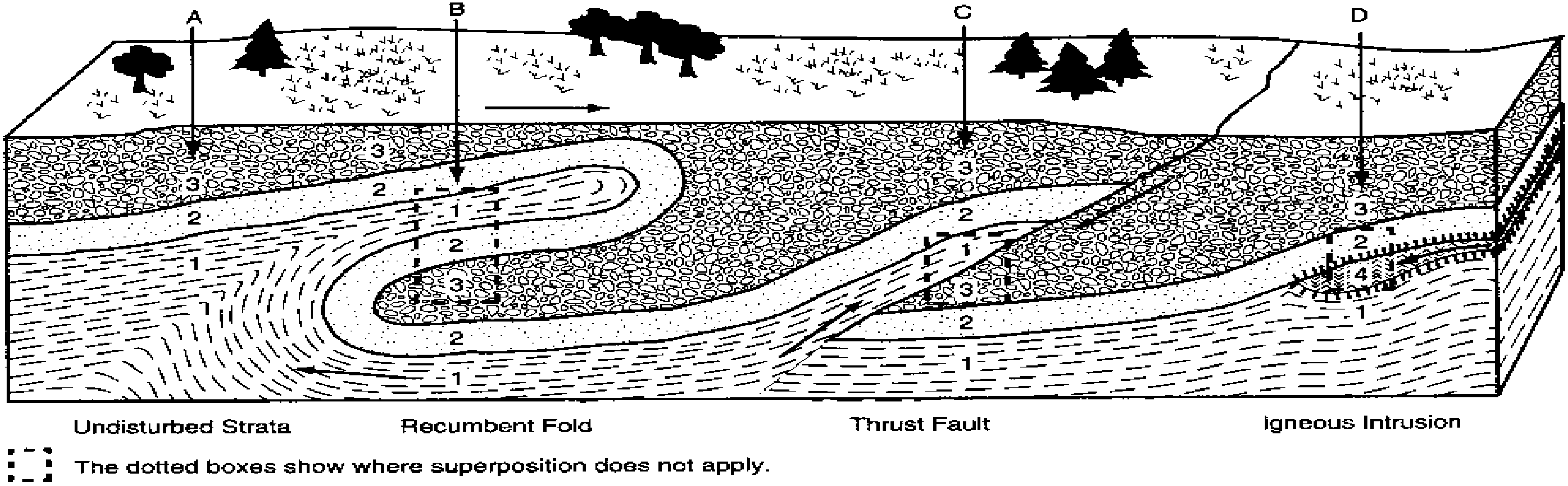
- In a series of sedimentary rocks the bottom layer is the oldest and the top layer is the youngest
  - Lower layers must be in place before younger rocks can be deposited on top of them
  - Exception: when something occurs to overturn layers

Grand Canyon



Law of Superposition

- Rock layers are older than folds found in them
  - Layers were there before they were folded



Law of Superposition

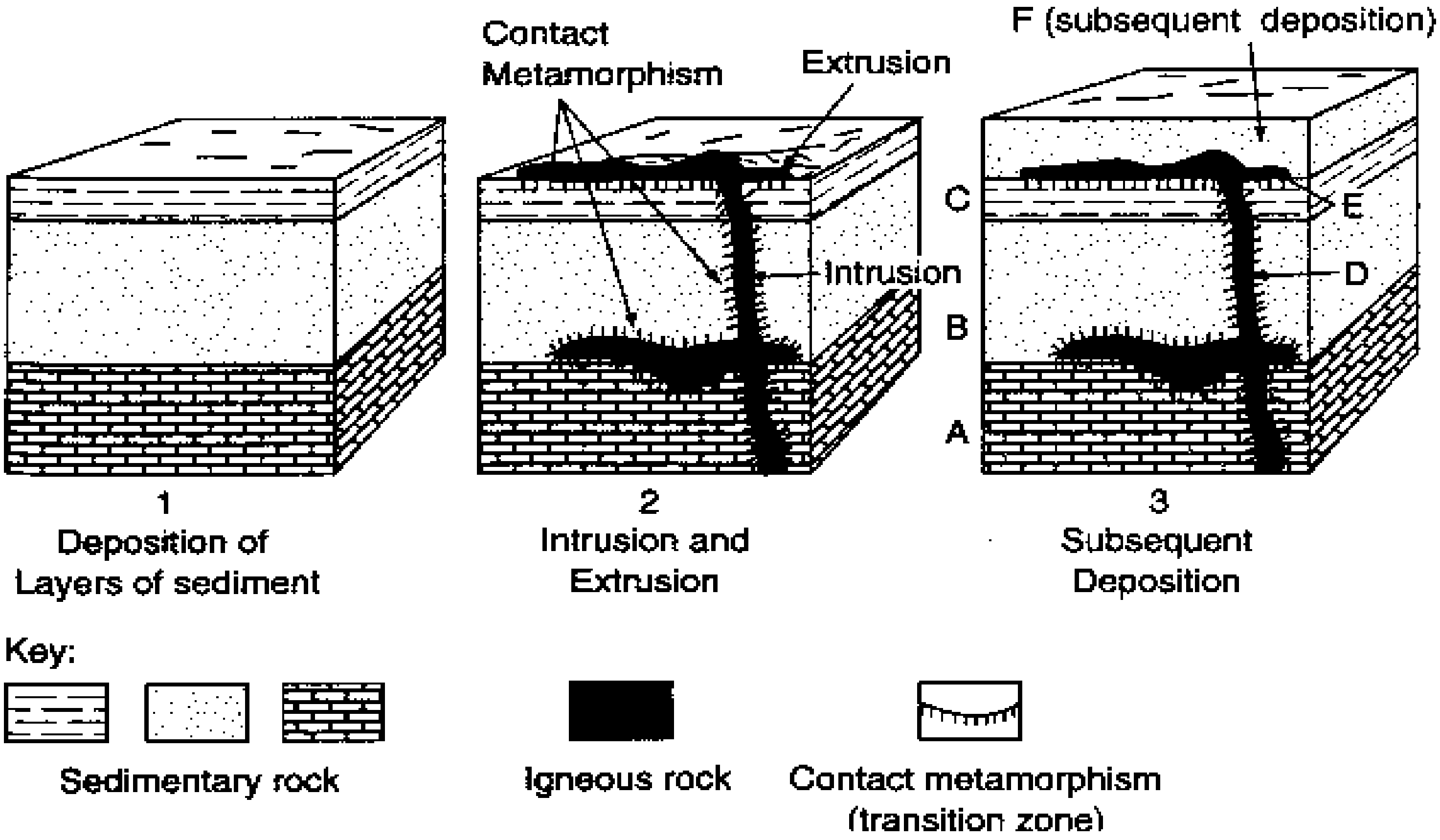
- Rock layers are older than faults found in them
- This is logical: you can’t break a rock if it does not exist; so rock containing a fault must be older than the fault

Law of Superposition

- Fossils are generally the same age as the rock layers in which they are found
  - Animal remains are deposited along with the sediments that will turn into sedimentary rocks

Law of Superposition

- Igneous intrusions are younger than the rock that they cut through or flow out of

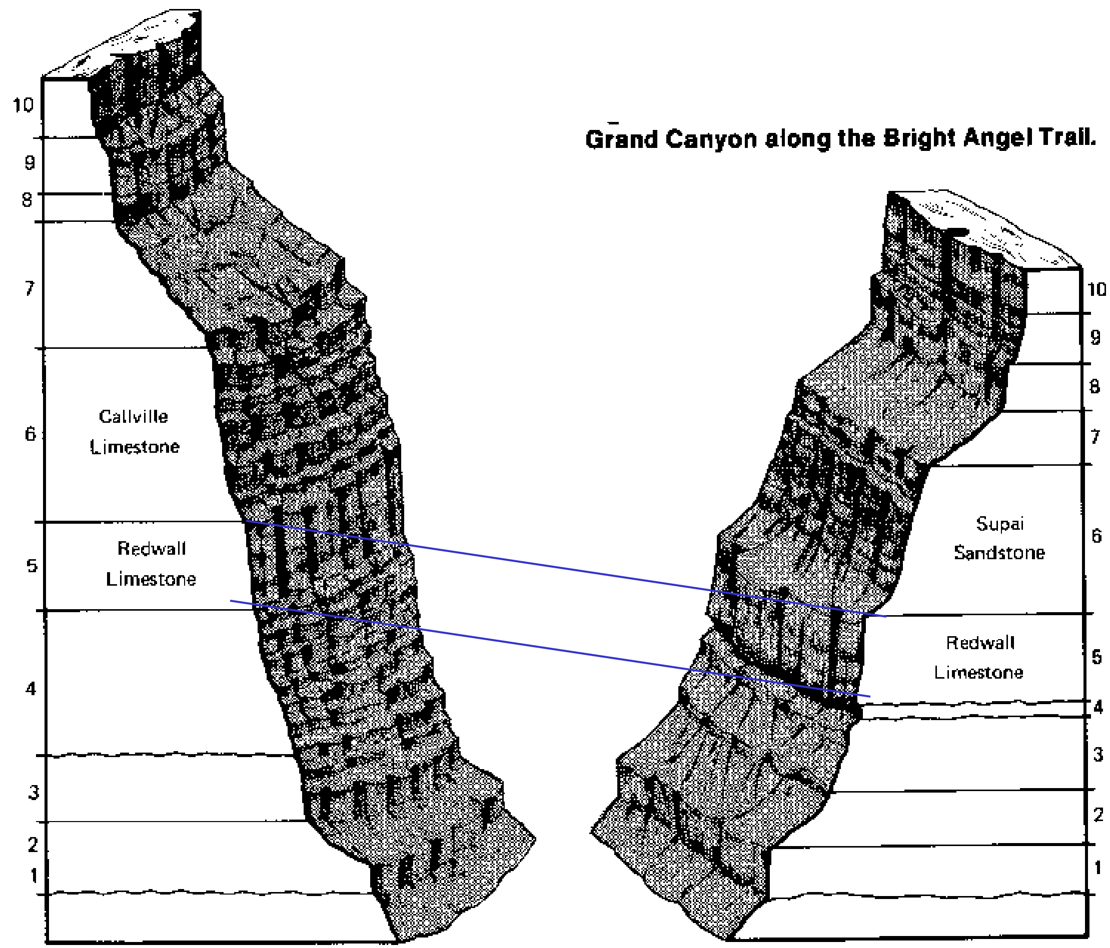


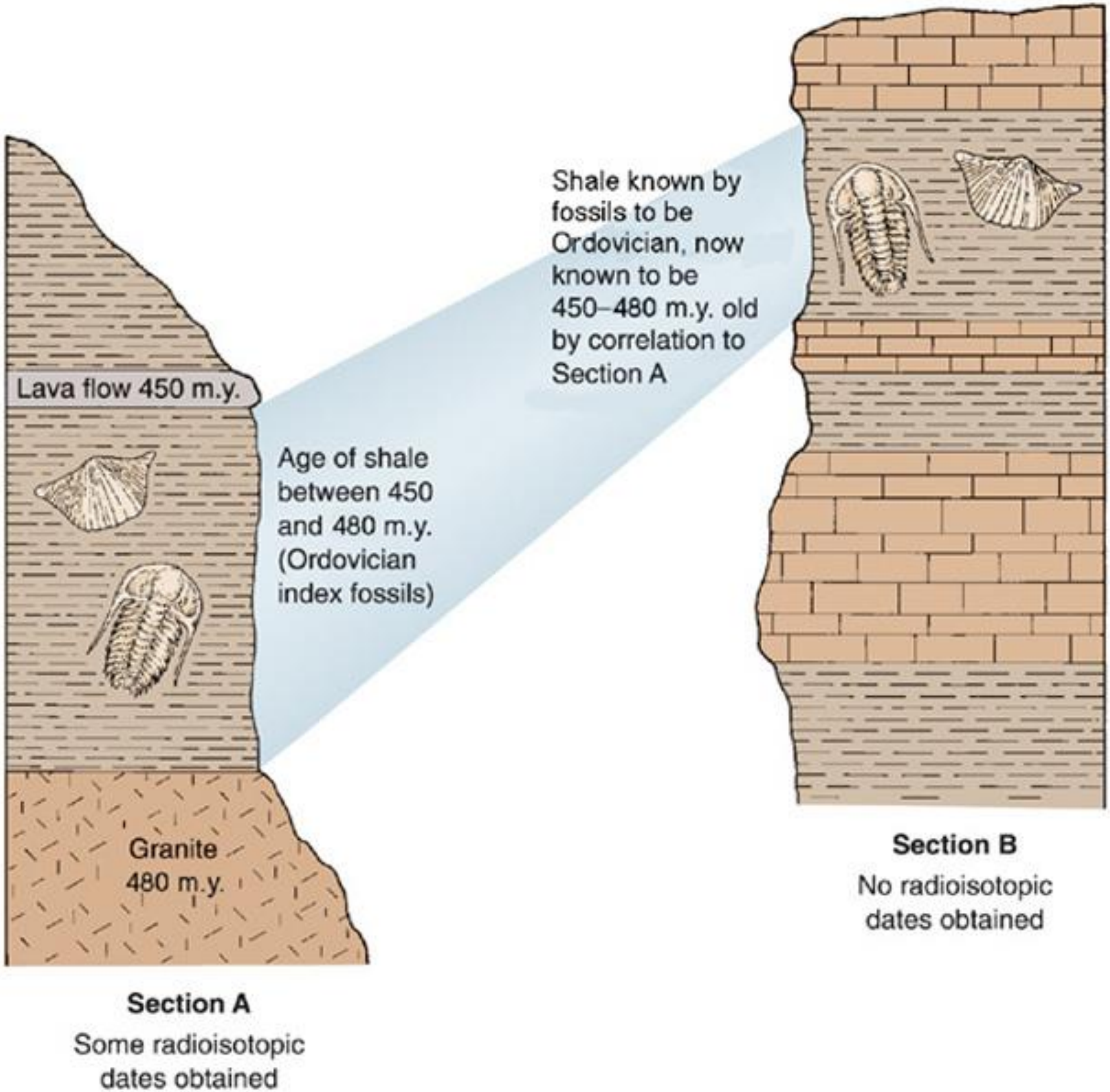
Igneous Intrusion - Cross Cutting

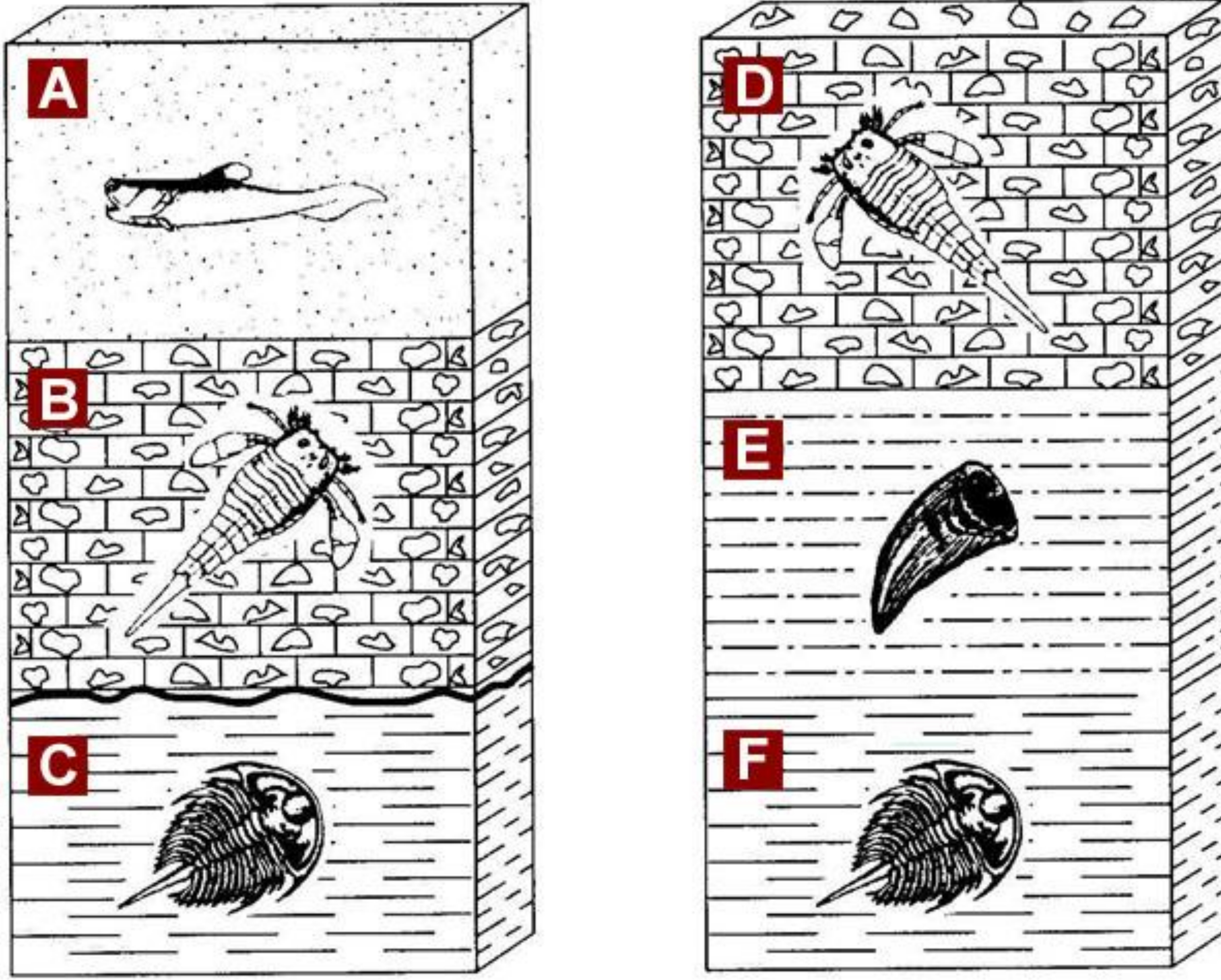
Correlation

Principle of lateral continuity

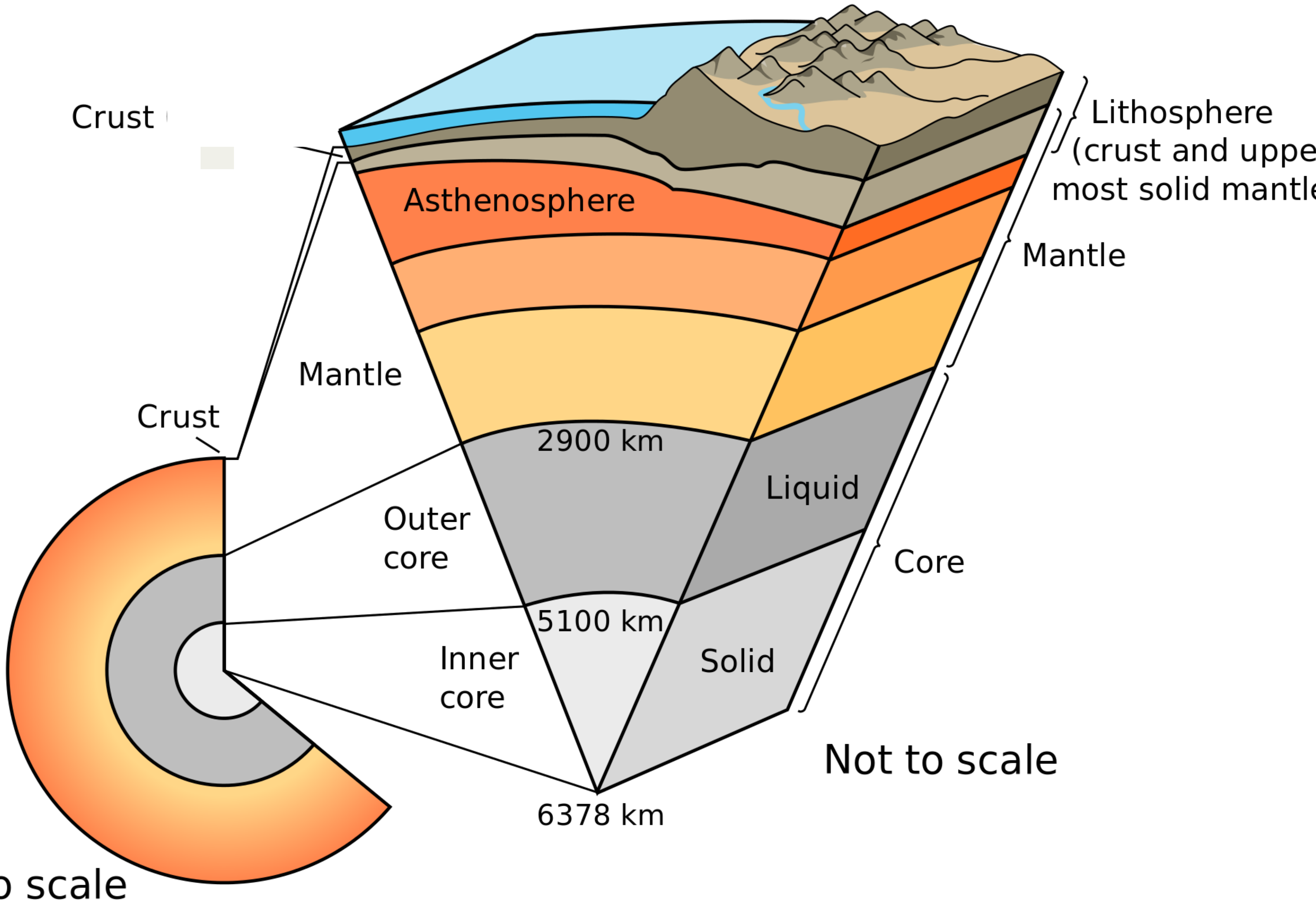
- Matching similar rock layers in different locations to see if they formed at the same time



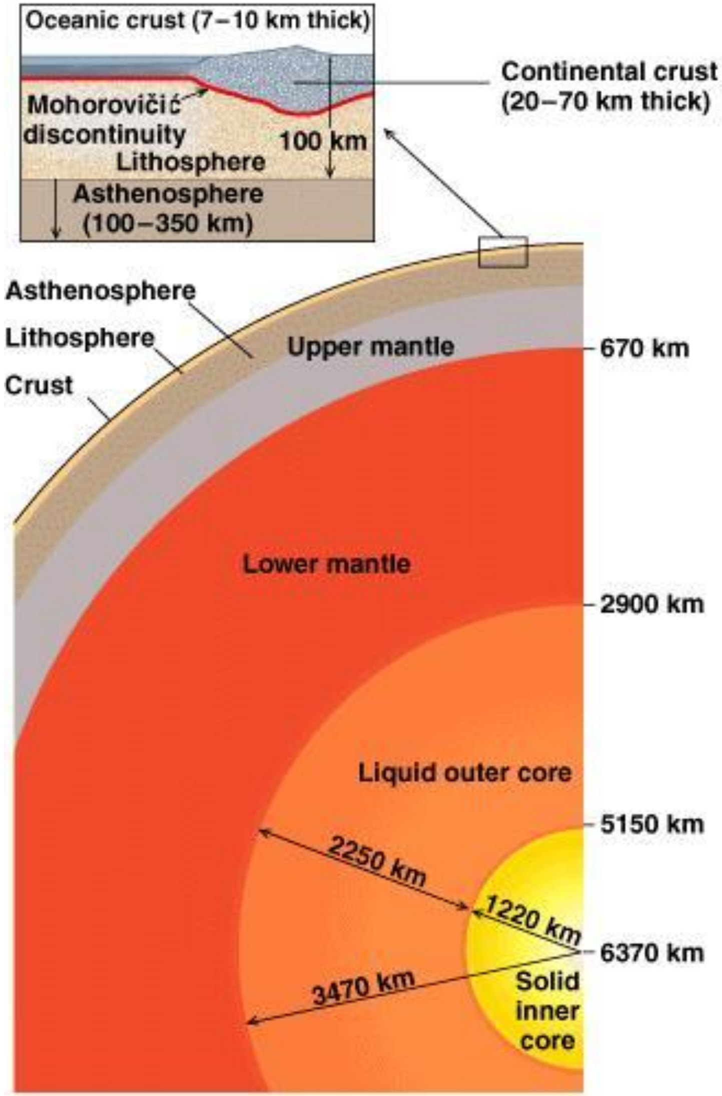

Lava flow 450 m.y.
Age of shale between 450 and 480 m.y. (Ordovician index fossils)
Shale known by fossils to be Ordovician, now known to be 450–480 m.y. old by correlation to Section A
Granite 480 m.y.
Section A
Some radioisotopic dates obtained
Section B
No radioisotopic dates obtained


A
B
C
D
E
F

Earth`s interior



Earth`s interior



Discontinuity

Mohorovicic discontinuity (Moho) separates the crust from the mantle.

Gutenberg discontinuity separates the mantle from the core

Evidence of Earth`s Internal structure and composition

- Meteorites
  - Use composition to determine composition of Earth

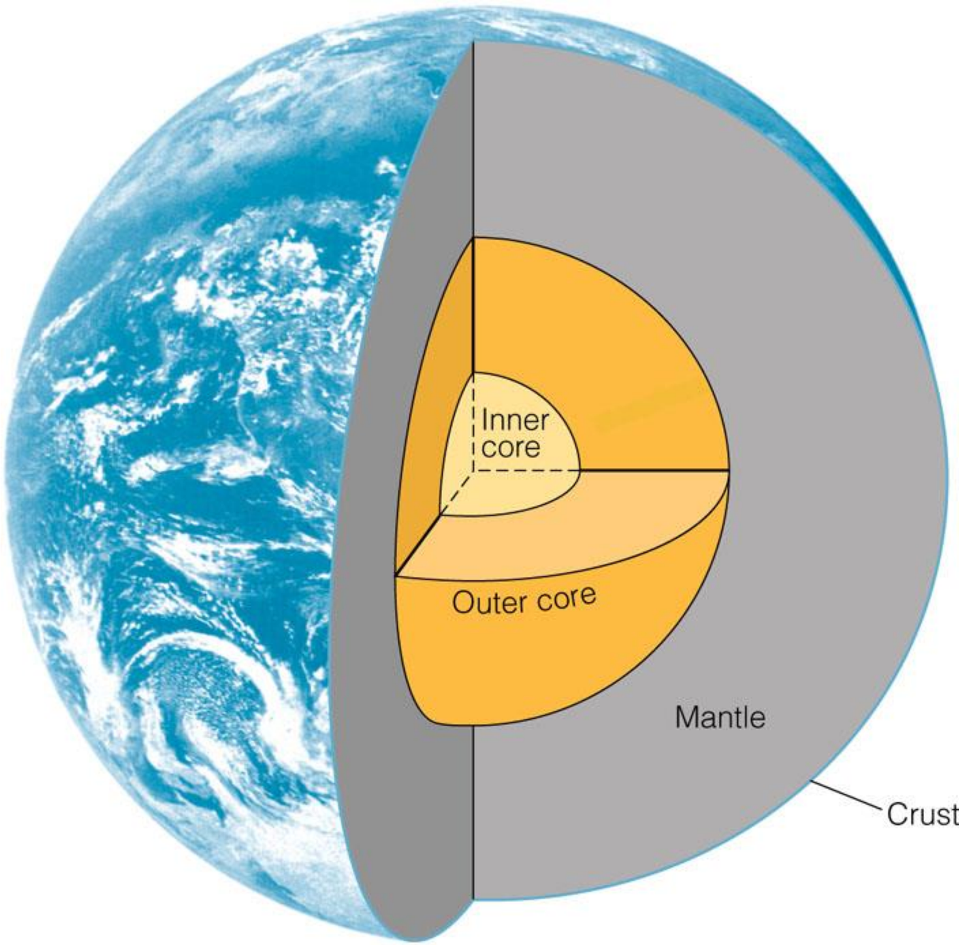
- Seismic waves
  - Travel times and direction give indication of internal structure of Earth

- Xenoliths

Xenolith

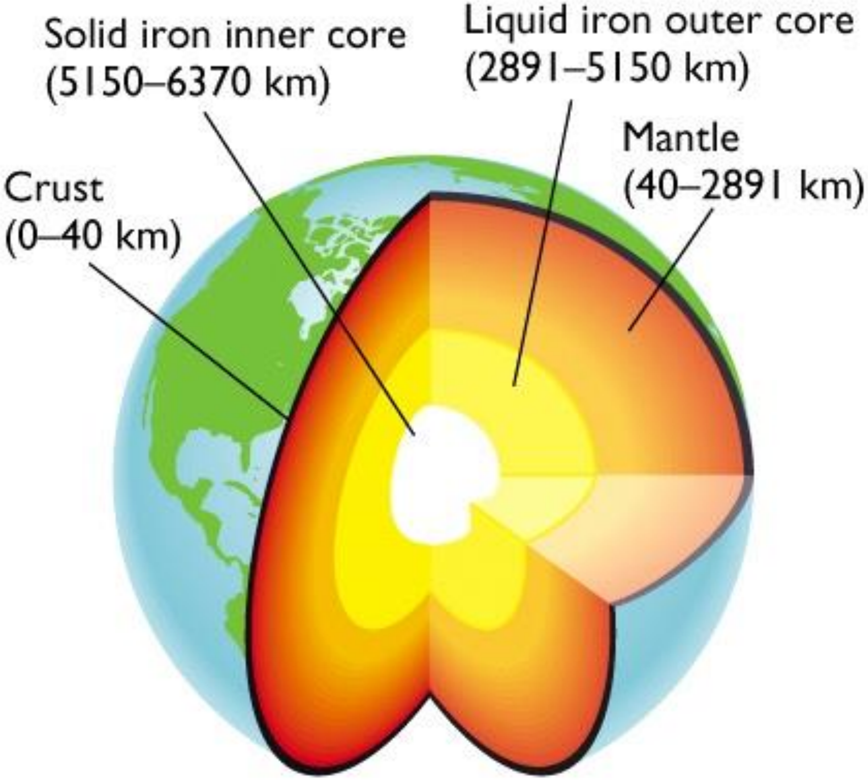
Rock fragment which becomes enveloped in a larger rock during the latter's development and hardening.

Earth`s interior



- Core
  - dense
  - Iron and Nickel
  - Inner Core - solid
  - Outer Core - liquid
- Mantle
  - Less dense than core
  - Iron and Magnesium silicates
  - Mostly solid
  - Upper mantle is partially molten
- Crust
  - Outermost layer
  - Very thin and rigid

The Earth today



Iron (heavy = dense) has moved to the center (close to the center of gravity)

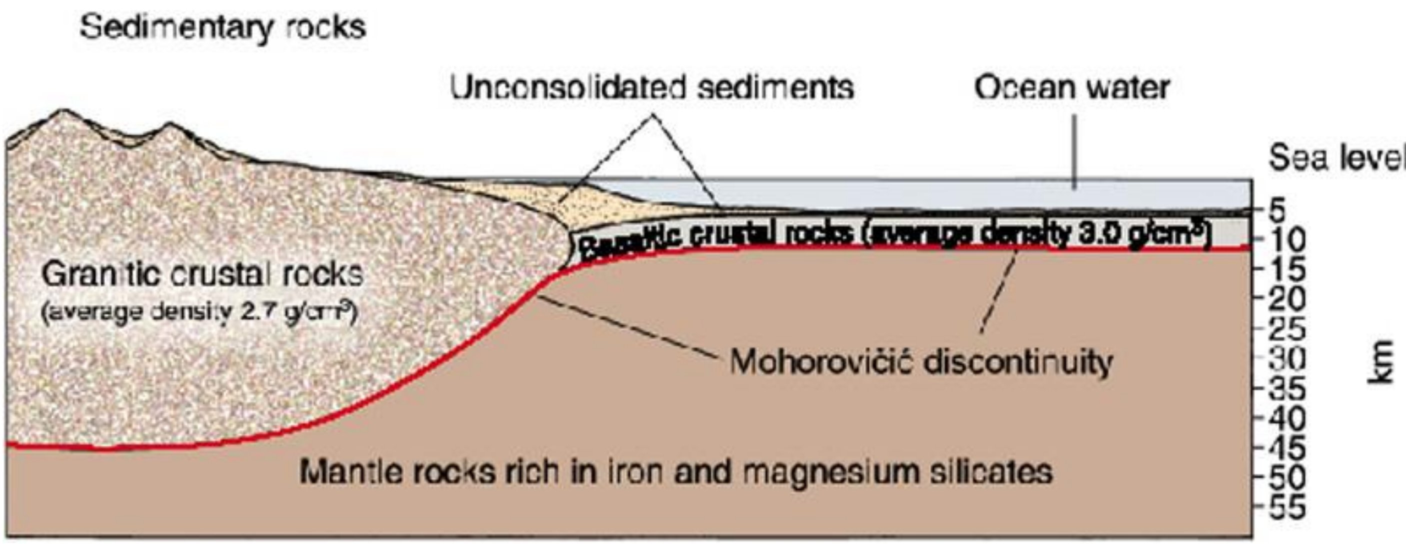
Rocks (lighter) are on the outside

Even for rocks denser minerals are inside (mantle) lighter silicates (structural silicates, felsic minerals) are in the crust

Crust

•**Continental Crust** (averages about 35 km thick; 60 km in mountain ranges; diagram shows range of 20-70 km)
Granitic composition
Less dense (about 2.7 g/cm^3).

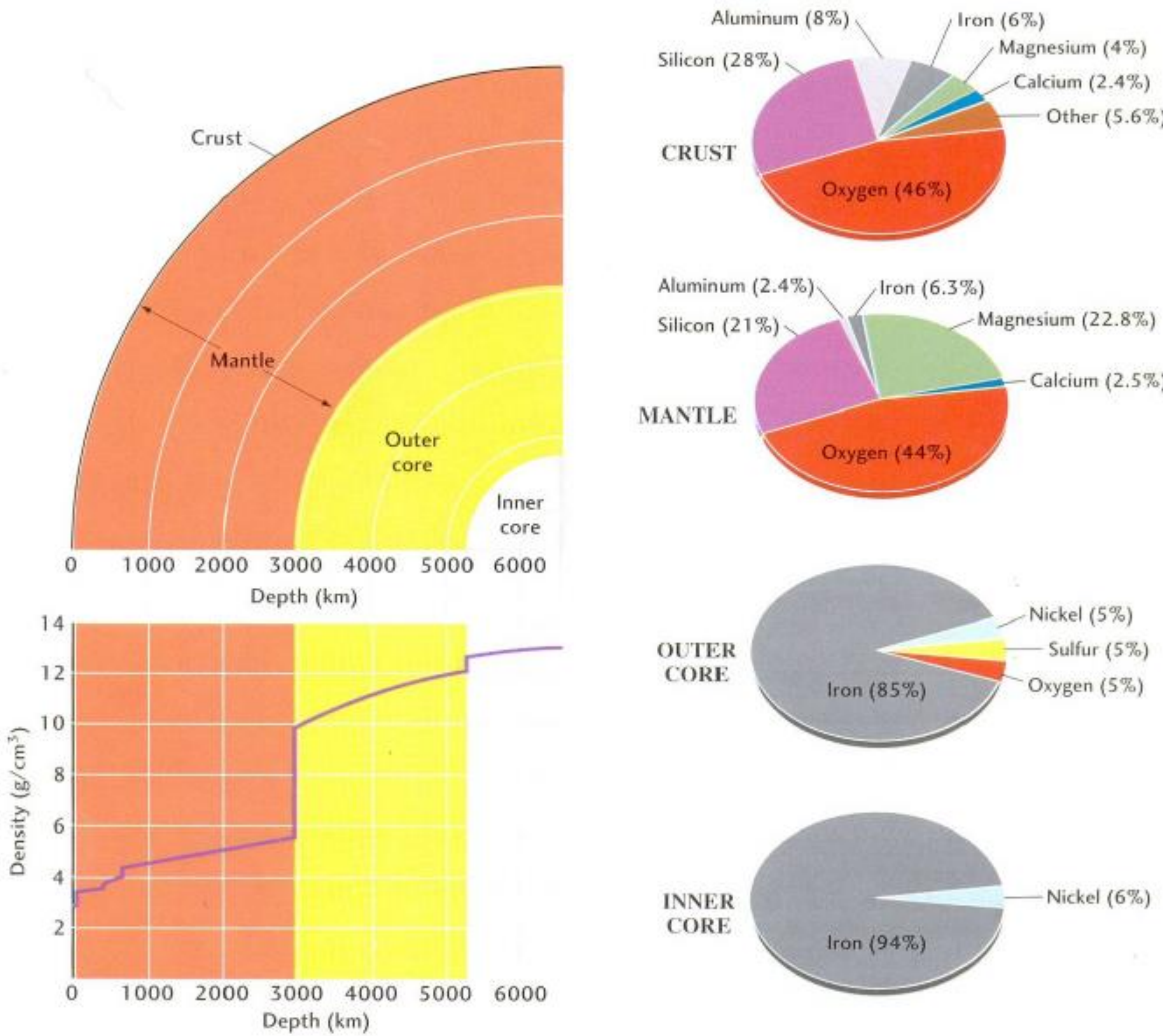
•**Oceanic Crust** (5 - 12 km thick)
Basaltic composition
More dense (about 3.0 g/cm^3).



Granite

Basalt

Relative abundance of elements



Relative abundance of elements

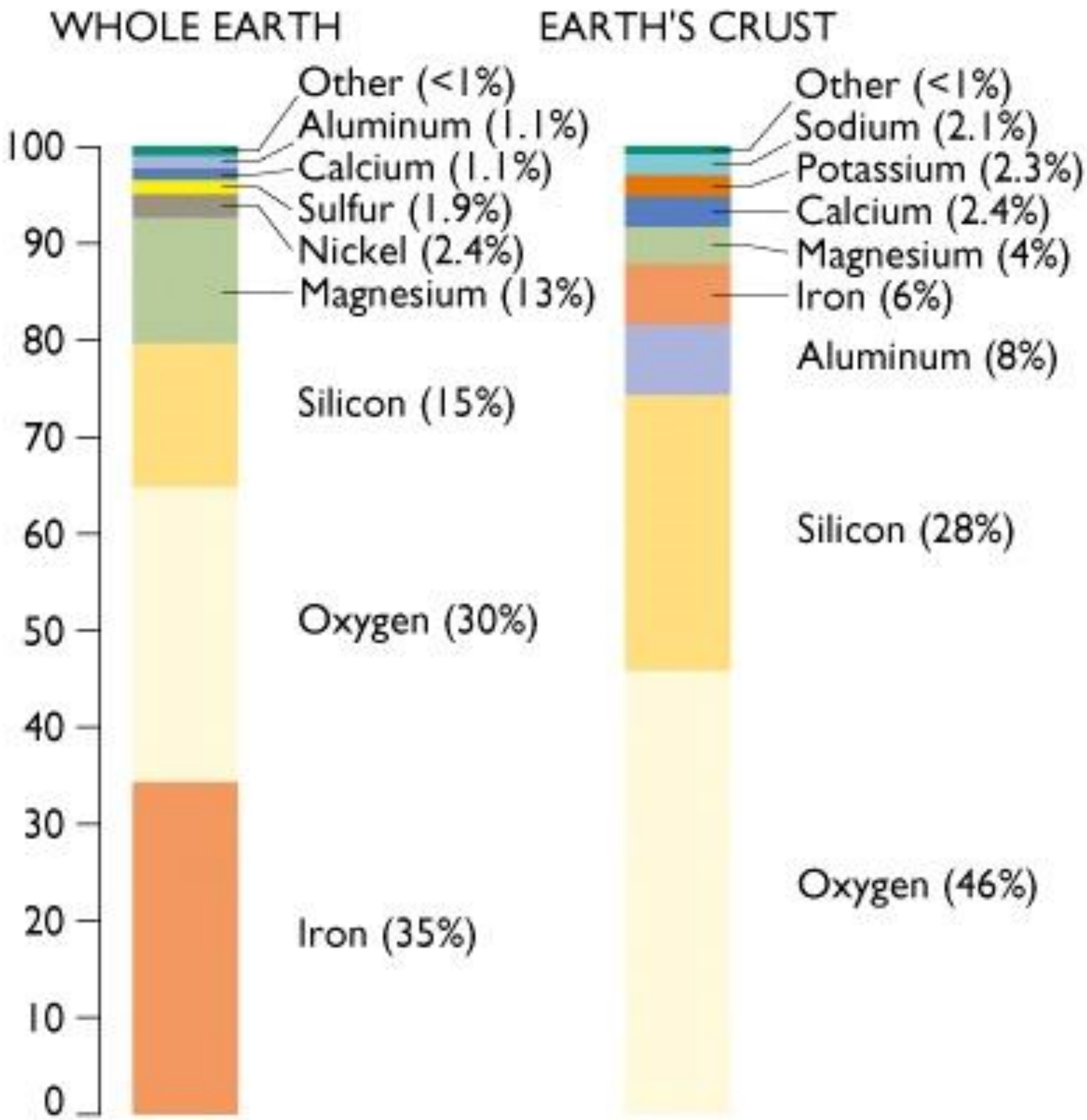


Fig. 1.7