



ECIV 3302
Engineering Geology

CHAPTER 1

AN INTRODUCTION TO GEOLOGY

Associate Professor Mazen Abualtayef

Civil and Environmental Engineering Department

Islamic University of Gaza, Palestine

The materials are mostly adapted from the presentation of Stan & Cindy Hatfield

Nisqually Glacier, Mt. Rainier, an volcano in the Cascade Range, WA.



Learning about geology will provide students with a greater appreciation and understanding of the natural features that shape the earth.



Learning about geology could save your life. Many geologic processes, such as landslides may pose significant hazards to the citizens who live in proximity, such as in Oso, Washington (March 22, 2014).



Learning about geology could save your life. Many geologic processes, such as volcanic eruptions may pose significant hazards to the citizens that live in their proximity, such as Mt. Pinatubo, Phillipines (1992).

The Science of Geology

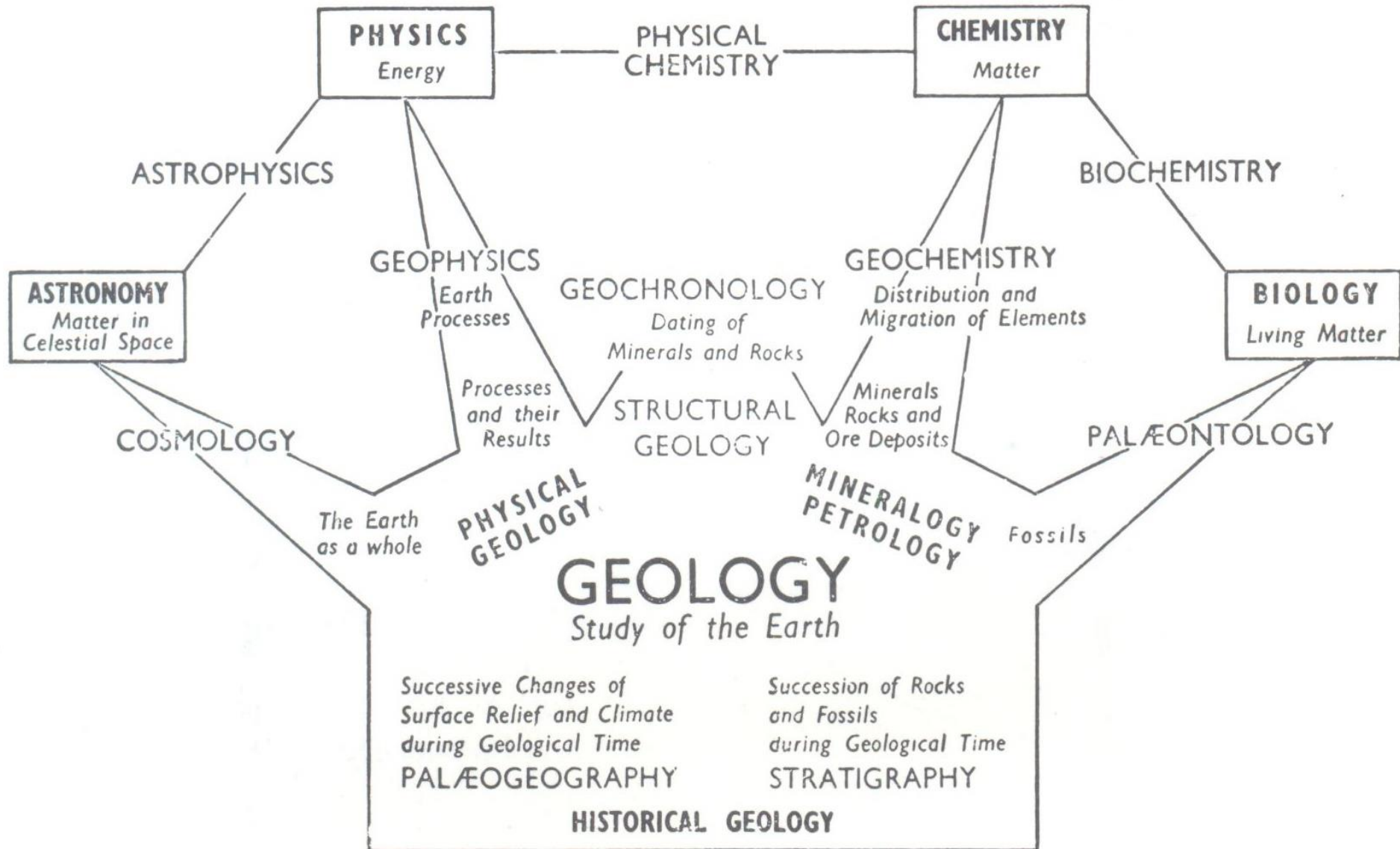
- **Geology** - “Geo” Earth; “ology” study of
- **Geology** - the science that pursues an understanding of planet earth
 - **Physical geology** - examines the materials composing earth and seeks to understand the many processes that operate beneath and upon its surface
 - **Historical geology** - seeks an understanding of the origin of earth and its development through time

The Science of Geology

- Geology, people, and the environment
 - Many important relationships exist between people and the natural environment
 - Problems and issues addressed by geology include:
 - Natural hazards,
 - Resources,
 - World population growth, and
 - Environmental issues



The Science of Geology



What is Physical Geology?

Erosion Wind
Soils
Water Oceans Glaciers
Weathering Underground Surface
Fossils Sedimentary
Earth History
Rocks
Volcanoes
Metamorphic Igneous
Earth's Interior
Plate Intrusions
Earthquakes **Tectonics**
Mountains Mineral Resources
Other Planets

Geology and other Sciences

Physics

- Geophysics
- Seismology

Chemistry

- Mineralogy
- Petrology
- Geochemistry

Biology

- Paleontology
- Paleo????ology

Astronomy

- Planetary Geology
- Helioseismology

Geology

- Economic Geology
- Hydrology
- Engineering Geology

- Historical Geology
- Geomorphology
- Oceanography
- Structural Geology
- Volcanology

Land

<i>Greatest known height:</i>	<i>Feet</i>	<i>Metres</i>
Mount Everest	29,028	8,848
Average height	2,757	840

Oceans and Seas

<i>Greatest known depth:</i>	<i>Feet</i>	<i>Metres</i>
Marianas Trench	36,204	11,035
Average depth	12,460	3,808

Size and Shape

	<i>Miles</i>	<i>Km</i>
Equatorial semi-axis, <i>a</i>	3,963.2	6,378.2
Polar semi-axis, <i>b</i>	3,950.0	6,356.8
Mean radius	3,956.4	6,371.0
Equatorial circumference	24,902	40,076
Polar (meridian) circumference	24,857	40,009
Ellipticity, $(a - b)/a$	1/298	

Area

	<i>Millions Sq. Miles</i>	<i>Millions Sq. Km</i>
Land (29.22 per cent)	57.5	149
Ice sheets and glaciers	6	15.6
Oceans & seas (70.78 per cent)	139.4	361
Land plus continental shelf	68.5	177.4
Oceans & seas minus continental shelf	128.4	332.6
Total area of the earth	196.9	510.0

Volume, Density and Mass

	<i>Average thickness or radius (km)</i>	<i>Volume ($\times 10^6 \text{ km}^3$)</i>	<i>Mean Density (g/cm^3)</i>	<i>Mass ($\times 10^{24} \text{ g}$)</i>
Atmosphere	—	—	—	0.005
Oceans and seas	3.8	1,370	1.03	1.41
Ice sheets and glaciers	1.6	25	0.90	0.023
Continental crust*	35	6,210	2.8	17.39
Oceanic crust†	8	2,660	2.9	7.71
Mantle	2,881	898,000	4.53	4,068
Core	3,473	175,500	10.72	1,881
Whole Earth	6,371	1,083,230	5.517	5,976

*Including continental shelves

†Excluding continental shelves

Some Geologic Rates

Cutting of Grand Canyon

- $2 \text{ km}/3 \text{ M.y.} = 1 \text{ cm}/15 \text{ yr}$

Uplift of Alps

- $5 \text{ km}/10 \text{ M.y.} = 1 \text{ cm}/20 \text{ yr.}$

Opening of Atlantic

- $5000 \text{ km}/180 \text{ M.y.} = 2.8 \text{ cm/yr.}$

Some Geologic Rates

Movement of San Andreas Fault

- $5 \text{ cm/yr} = 7 \text{ m/140 yr.}$

Growth of Mt. St. Helens

- $3 \text{ km/30,000 yr} = 10 \text{ cm/yr.}$

Deposition of Niagara Dolomite

- $100 \text{ m/ 1 M.y.?} = 1 \text{ cm/100 yr.}$

The Science of Geology

- Some historical notes about geology
 - The nature of earth has been a focus of study for centuries
 - **Catastrophism**, “features such as mountains were produced by sudden worldwide disasters.”
 - **Uniformitarianism** and the birth of modern geology
“the present is the key of the past”

Geologic Time

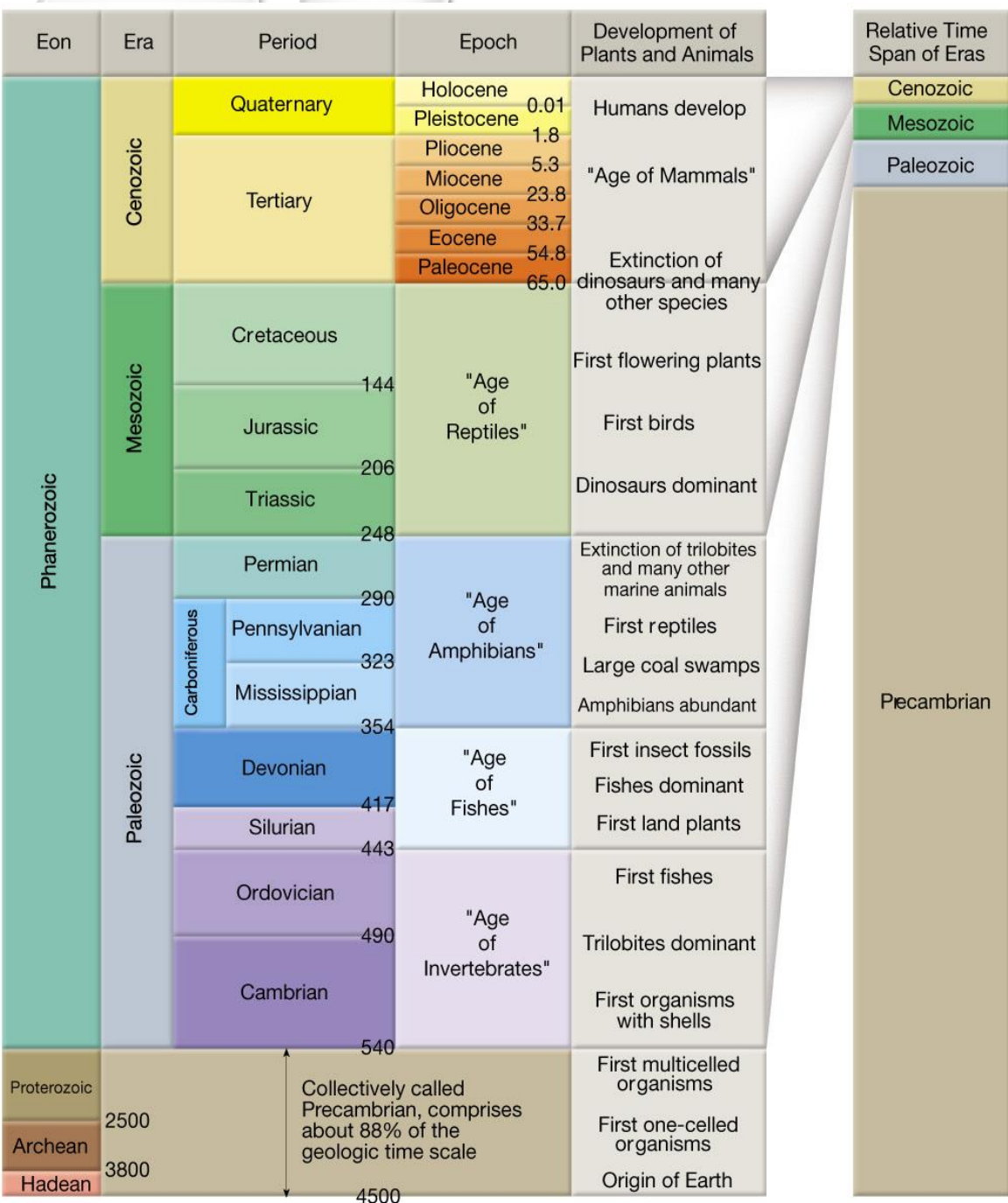
- Geologists are now able to assign fairly accurate dates to events in earth history
- **Relative dating:** means that dates are placed in their proper sequence or order without knowing their age in years
- **Absolute dating**

Geologic Time

- The magnitude of geologic time involves vast times – millions or billions of years
- An appreciation for the magnitude of geologic time is important because many processes are very gradual
- The big difference between geology and other sciences: TIME (geologically speaking, not much happens in a human lifetime!)
- Therefore, geologists use millions of years as the standard unit of time

Age of Earth

- ~ 4,600 million years
- Radioactive minerals
 - Radium, uranium, lead
- Salts in the oceans and its accumulation (not accurate)
- For younger ages, deposits and C^{14}



The geologic time scale

Figure 1.8

The Nature of Scientific Inquiry

- Science assumes the natural world is consistent and predictable
- Goal of science is to discover patterns in nature and use the knowledge to make predictions
- Scientists collect data through observation and measurements

The Nature of Scientific Inquiry

- How or why things happen is explained using a
 - **Hypothesis** – a tentative (or untested) explanation
 - **Theory** – a well-tested and widely accepted view that the scientific community agrees best explains certain observable facts

The Nature of Scientific Inquiry

- Scientific method involves
 - Gathering facts through observations
 - Formulation of hypotheses and theories
- There is no fixed path that scientists follow that leads to scientific knowledge

A View of Earth

- Earth is a planet that is small and self-contained
- Earth's four spheres
 - Hydrosphere
 - Atmosphere
 - Biosphere
 - Solid earth



Earth as a System

- Earth is a dynamic planet with many interacting parts or spheres
- Earth system science
 - Aims to study earth as a system composed of numerous interacting parts or **subsystems**
 - Employs an interdisciplinary approach to solve global environmental problems

Earth as a System

- What is a **system**
 - Any size group of interacting parts that form a complex whole
 - Open vs. Closed systems
- Feedback mechanisms
 - Negative feedback – maintains the status quo
 - Positive feedback – enhances or drives changes

Earth as a System

- The earth system is powered by the sun that drives external processes in the
 - Atmosphere
 - Hydrosphere
 - At earth's surface
- The earth system is also powered by earth's interior
- External energy (sun).... Wind, waves...
- Internal energy... Earthquake, volcanoes

Rocks and the Rock Cycle

- Basic rock types

- Igneous rocks

- Cooling and solidification of **magma** (molten rock)
 - Examples include **granite** and **basalt**

- Sedimentary rocks

- Accumulate in layers at earth's surface
 - Sediments are derived from weathering of preexisting rocks
 - Examples include **sandstone** and **limestone**

Rocks and the Rock Cycle

- Basic rock types
 - Metamorphic rocks
 - Formed by “changing” preexisting igneous, sedimentary or other metamorphic rocks
 - Driving forces are increased heat and pressure
 - Examples include gneiss and marble

Rocks and the Rock Cycle

- The **rock cycle**: one of earth's subsystems
 - The loop that involves the processes by which one rock changes to another
 - Illustrates the various processes and paths as earth materials change both on the surface and inside the earth

The rock cycle

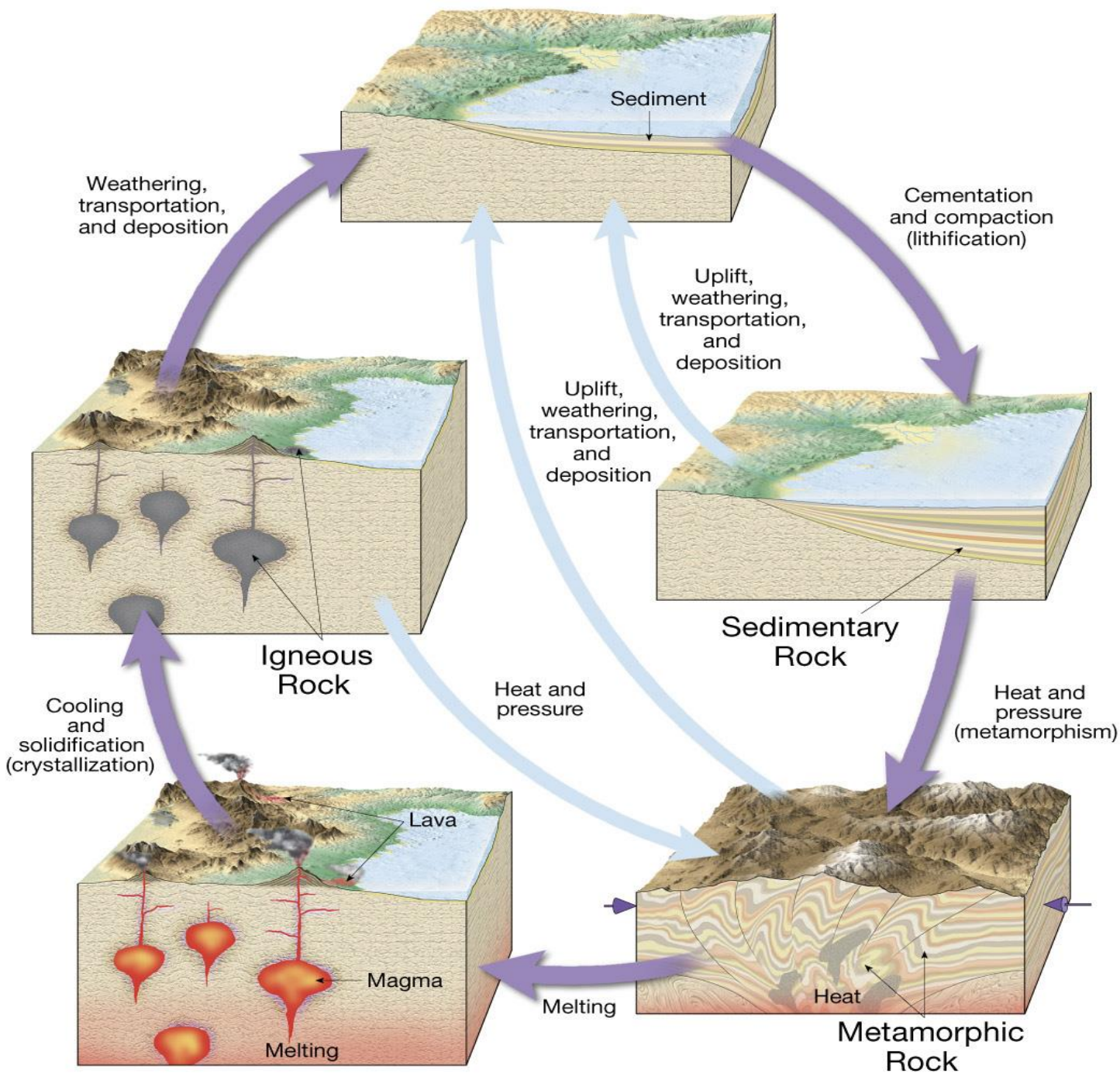


Figure 1.22

Early Evolution of Earth

- Origin of planet Earth
 - Most researchers believe that earth and the other planets formed at essentially the same time

Early Evolution of Earth

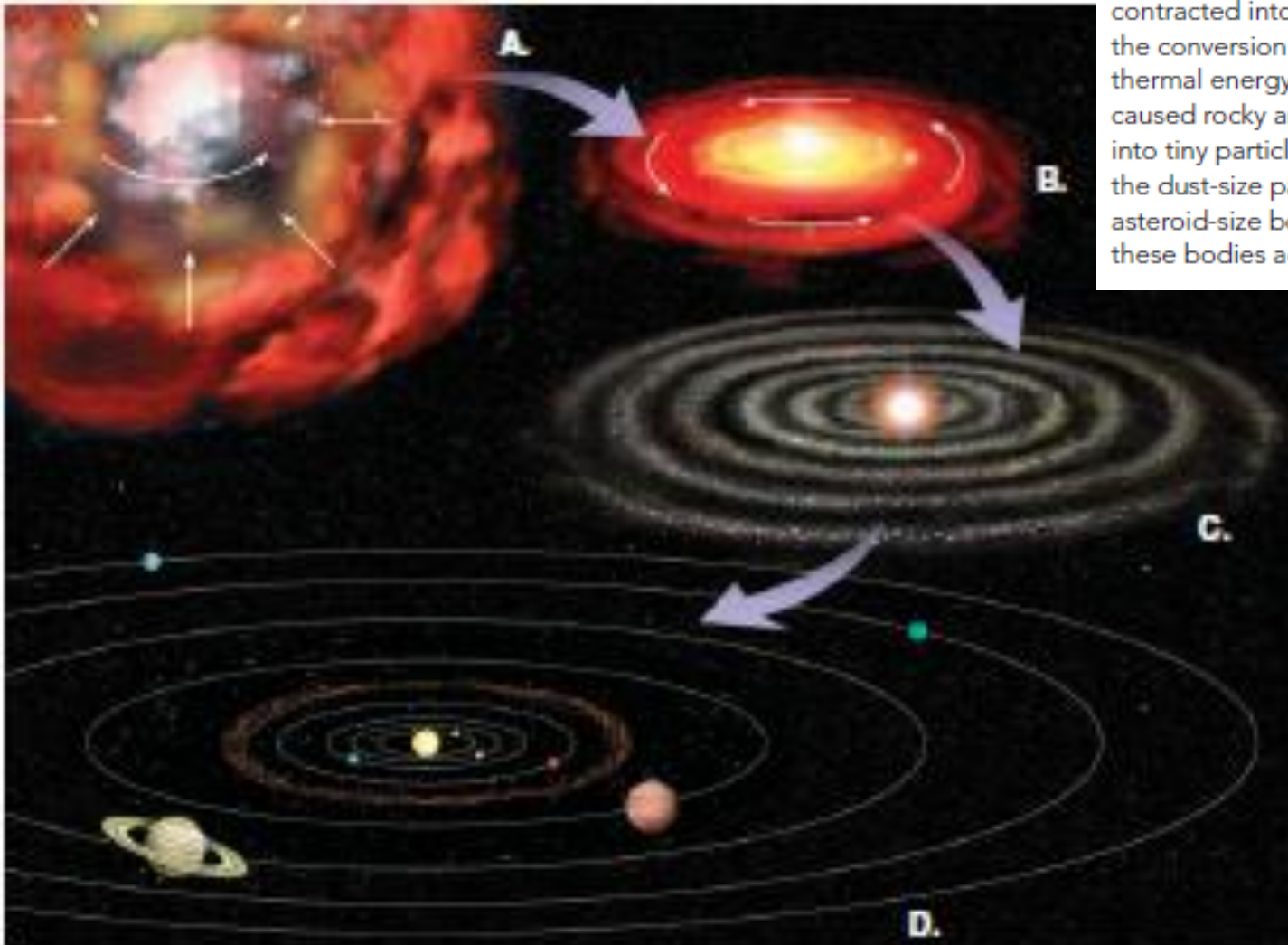
- Origin of planet earth
 - Nebular hypothesis
 - Rotating cloud called the solar nebula
 - Composed of hydrogen and helium
 - Nebula began to contract about 5 billion years ago
 - Assumes a flat, disk shape with the protosun (pre-sun) at the center
 - Inner planets begin to form from metallic and rocky substances
 - Larger outer planets began forming from fragments of ices (H_2O , CO_2 , and others)

Early Evolution of Earth

- Formation of earth's layered structure
 - Metals sank to the center
 - Molten rock rose to produce a primitive crust
 - Chemical segregation established the three basic divisions of earth's interior
 - Primitive atmosphere evolved from gases in earth's interior

Evolution of the Solar System

FIGURE 1.23 Formation of the solar system according to the nebular theory. **A.** The birth of our solar system began as dust and gases (nebula) started to gravitationally collapse. **B.** The nebula contracted into a rotating disk that was heated by the conversion of gravitational energy into thermal energy. **C.** Cooling of the nebular cloud caused rocky and metallic material to condense into tiny particles. **D.** Repeated collisions caused the dust-size particles to gradually coalesce into asteroid-size bodies. Within a few million years these bodies accreted into the planets.



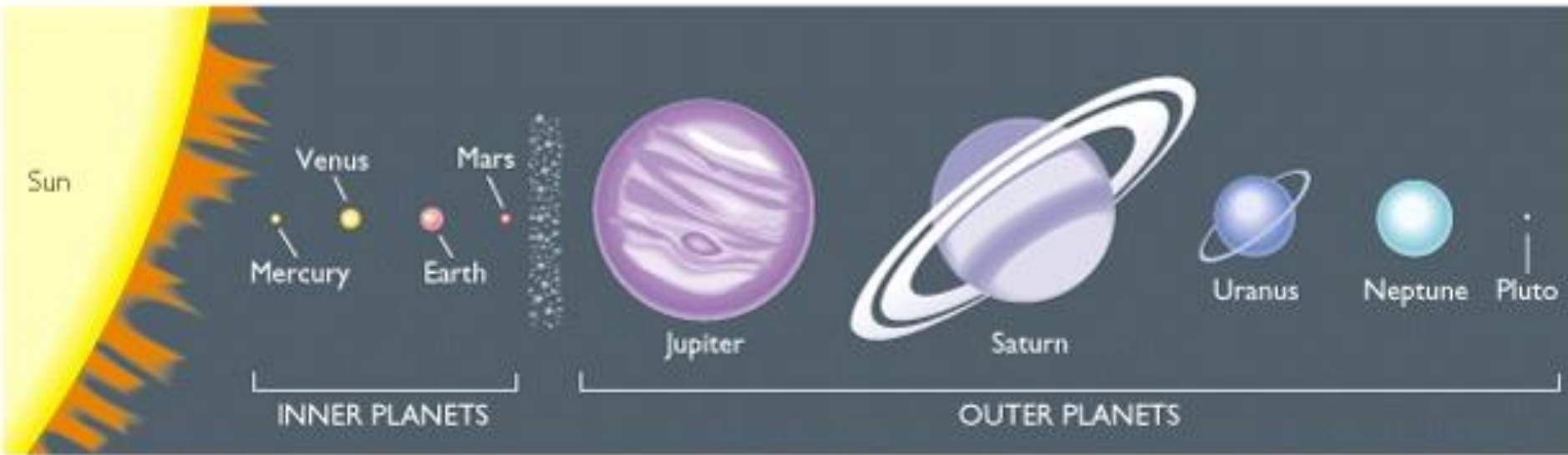
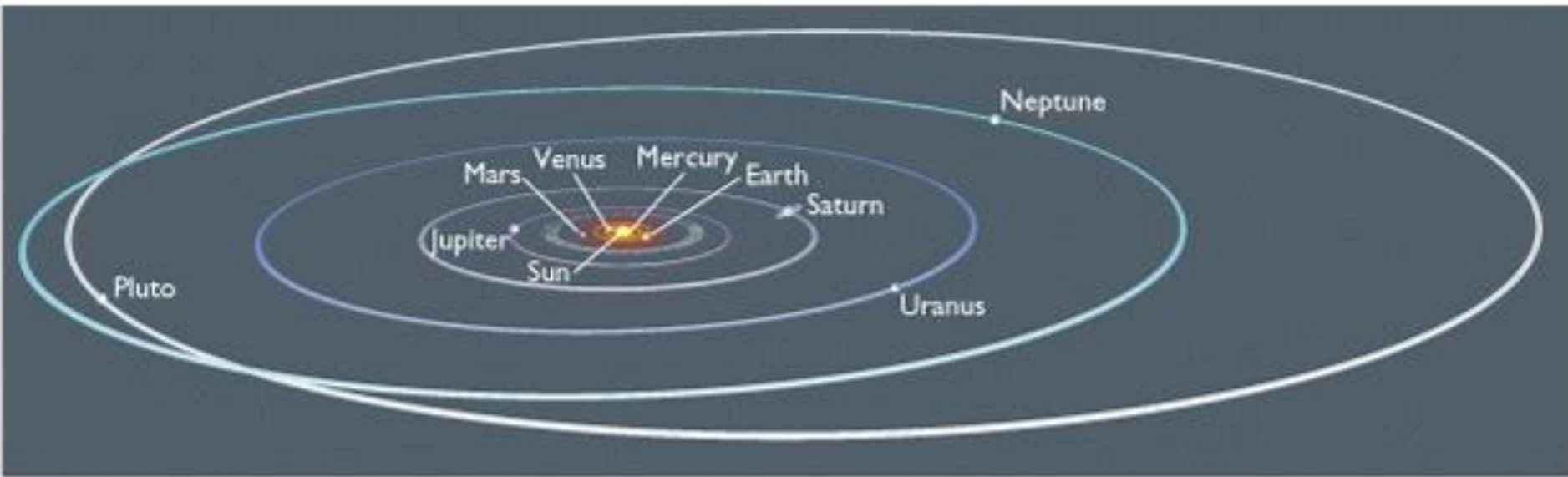
Evolution of the Solar System



FIGURE 1.24 Lagoon Nebula. It is in glowing clouds like these that gases and dust particles become concentrated into stars. (Courtesy of National Optical Astronomy Observatories)

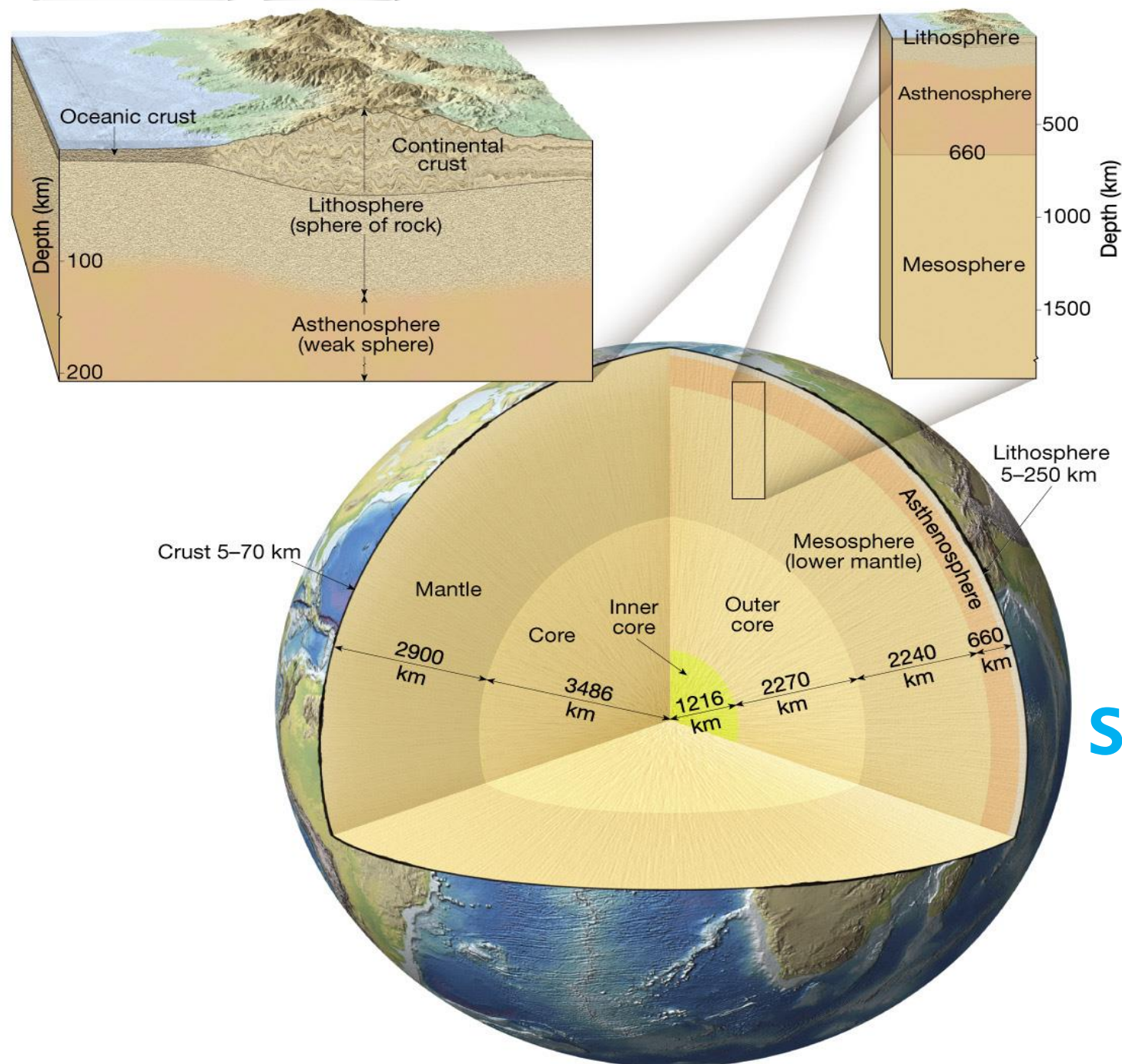
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Go to Settings to activate Windows

The Solar System



Earth's Internal Structure

- Layers defined by composition
 - Crust
 - Mantle
 - Core
- Layers defined by physical properties
 - Lithosphere
 - Asthenosphere
 - Mesosphere
 - Inner and outer core



Earth's layered structure

Figure 1.26

The Face of Earth

- Earth's surface

- Continents

- Oceans

- a. **Continents**

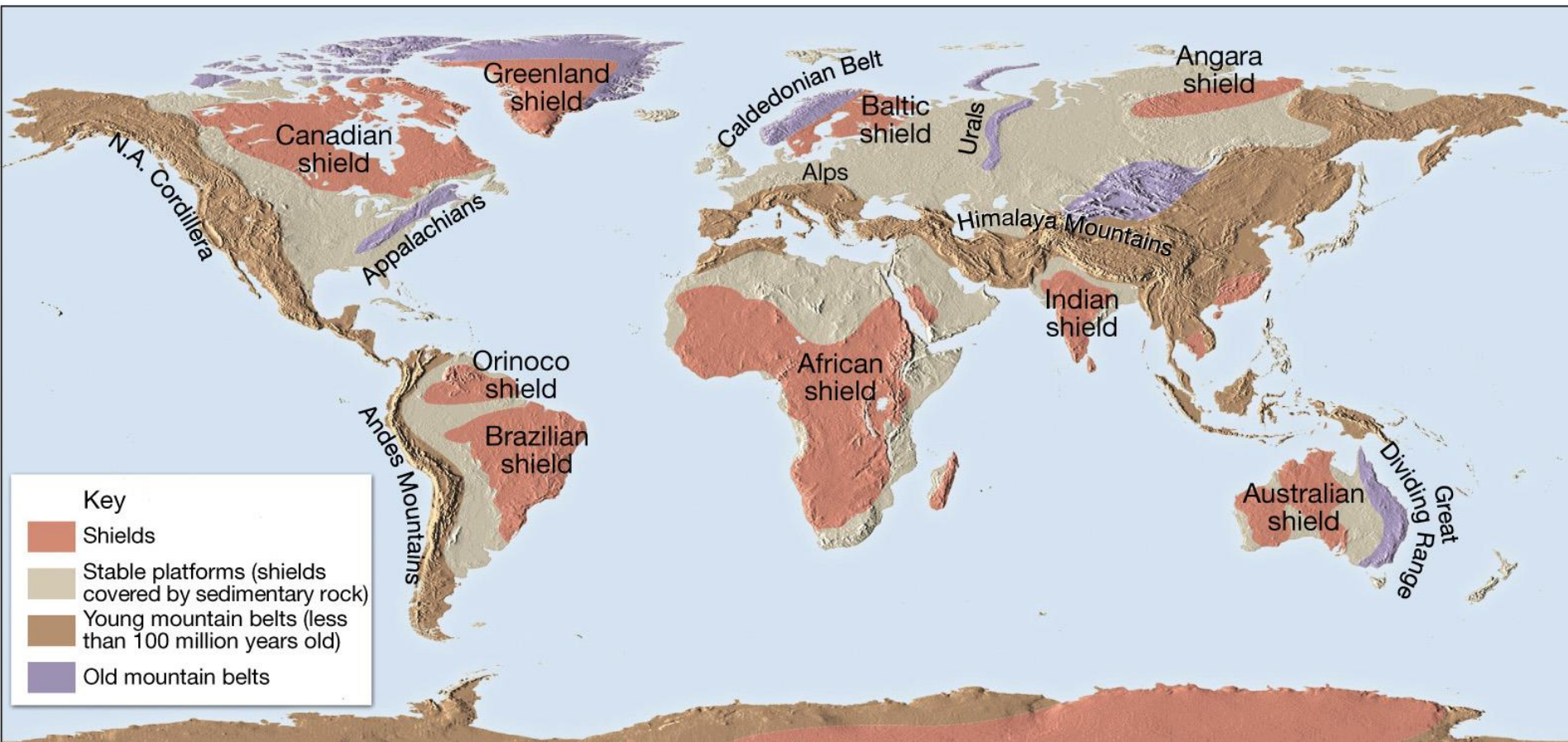
- 1. Mountain belts

- Most prominent feature of continents

- 2. The stable interior

- Also called a **craton** – composed of **shields** and stable **platforms**

The Continents



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The Face of Earth

b. Ocean basins

1. Continental margins

- Includes the continental shelf, continental slope, and the continental rise

2. Deep-ocean basins

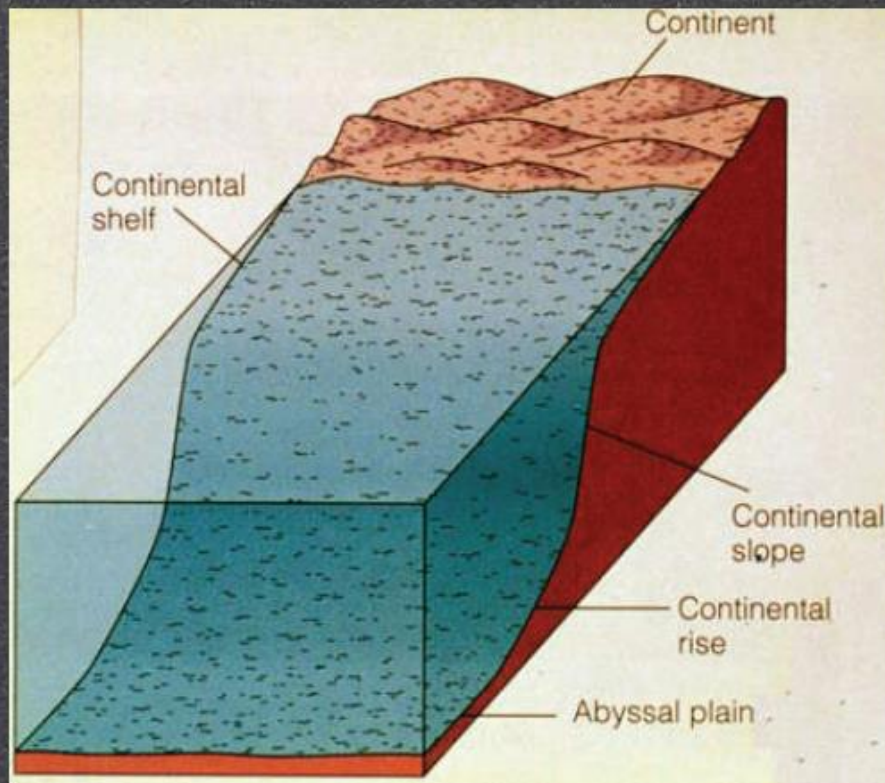
- Abyssal plains
- Oceanic trenches
- Seamounts

3. Oceanic ridge system

- Most prominent topographic feature on earth
- Composed of igneous rock that has been fractured and uplifted

The Face of Earth

Characteristics of Sea Floor

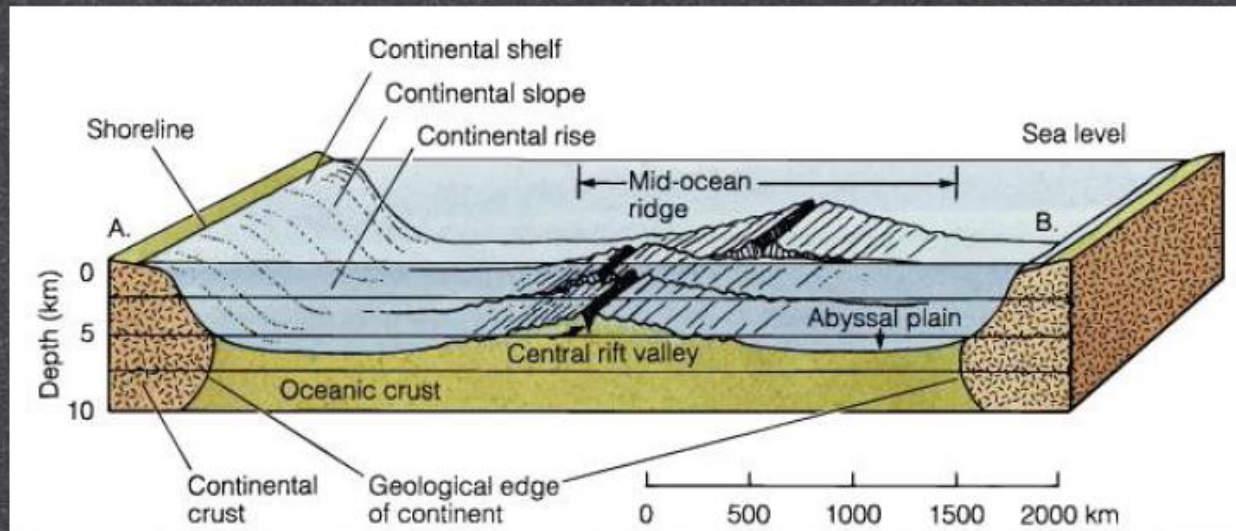


**continental
margins
(underlain by
continental crust)**

- continental shelf
- continental slope
- continental rise

The Face of Earth

Characteristics of Deep Ocean

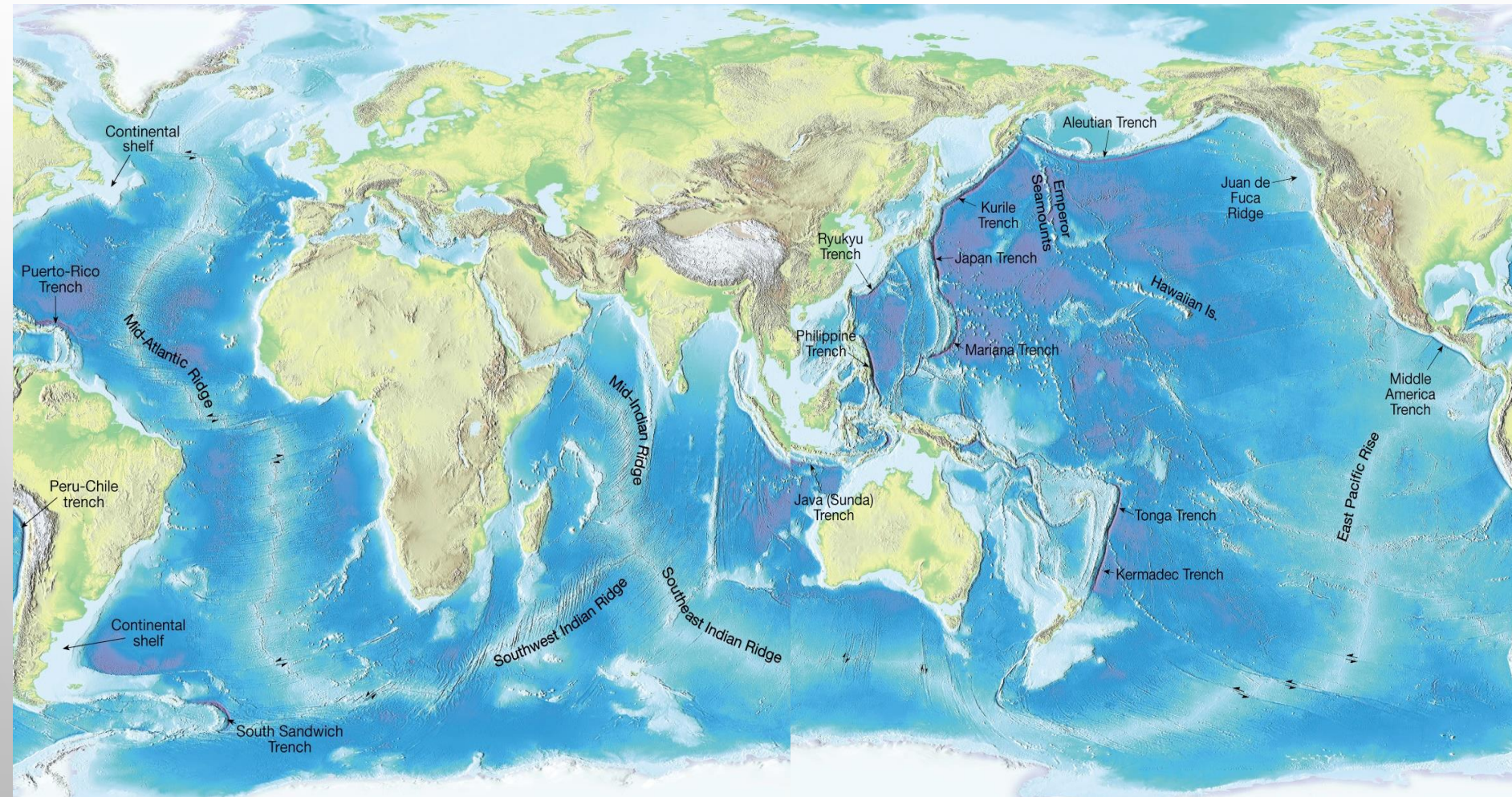


30% of Earth

- abyssal plains

- flat areas covering much of sea floor
- average 3.8 km deep, covered with fine-grained sediment, dark with little or no life

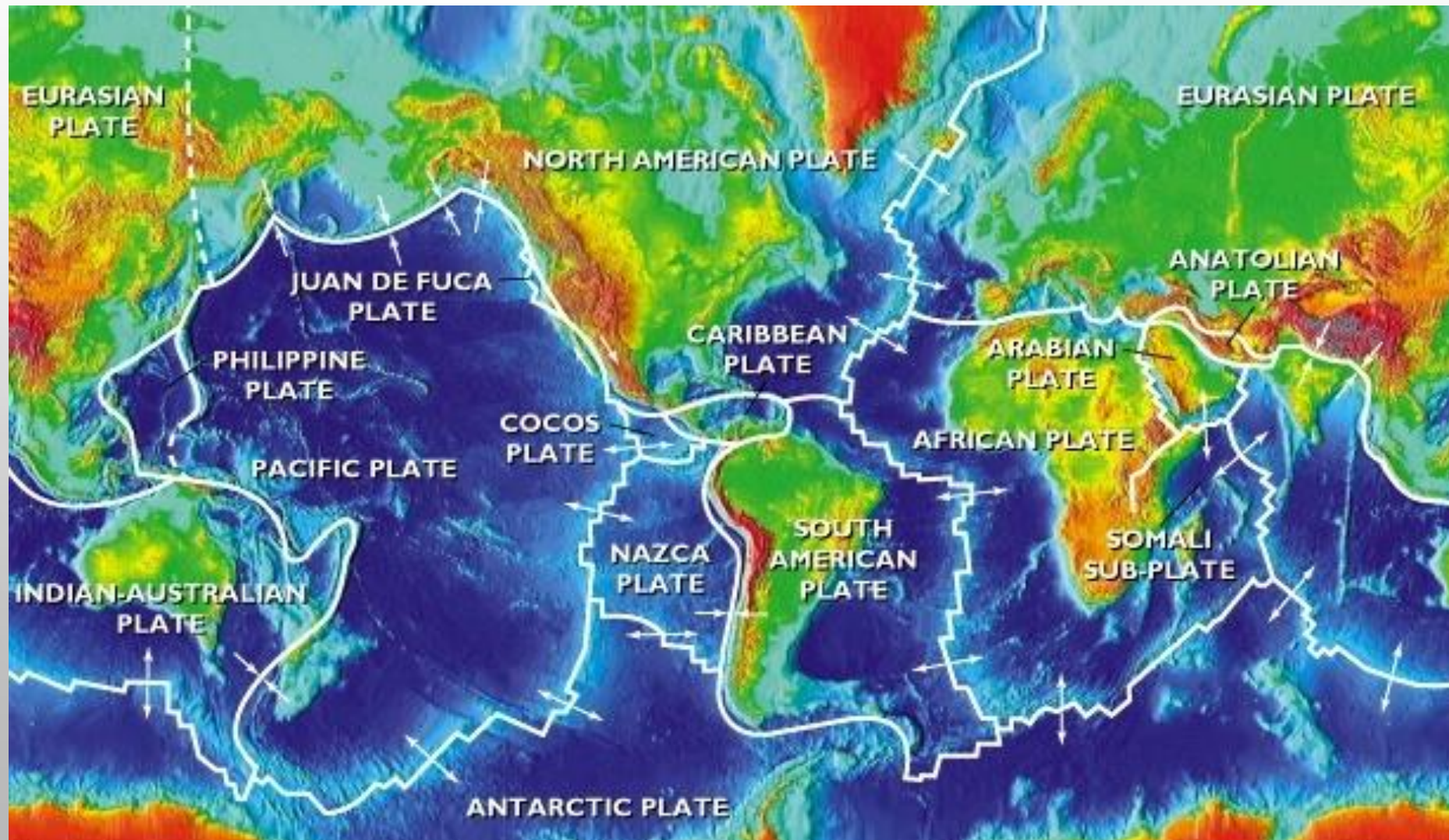
Oceanic Ridge System



Dynamic Earth

- The theory of plate tectonics
 - Involves understanding the workings of our dynamic planet
 - Began in the early part of the twentieth century with a proposal called continental drift – the idea that continents moved about the face of the planet
 - Theory, called plate tectonics has now emerged that provides geologists with the first comprehensive model of earth's internal workings

Tectonic Plates



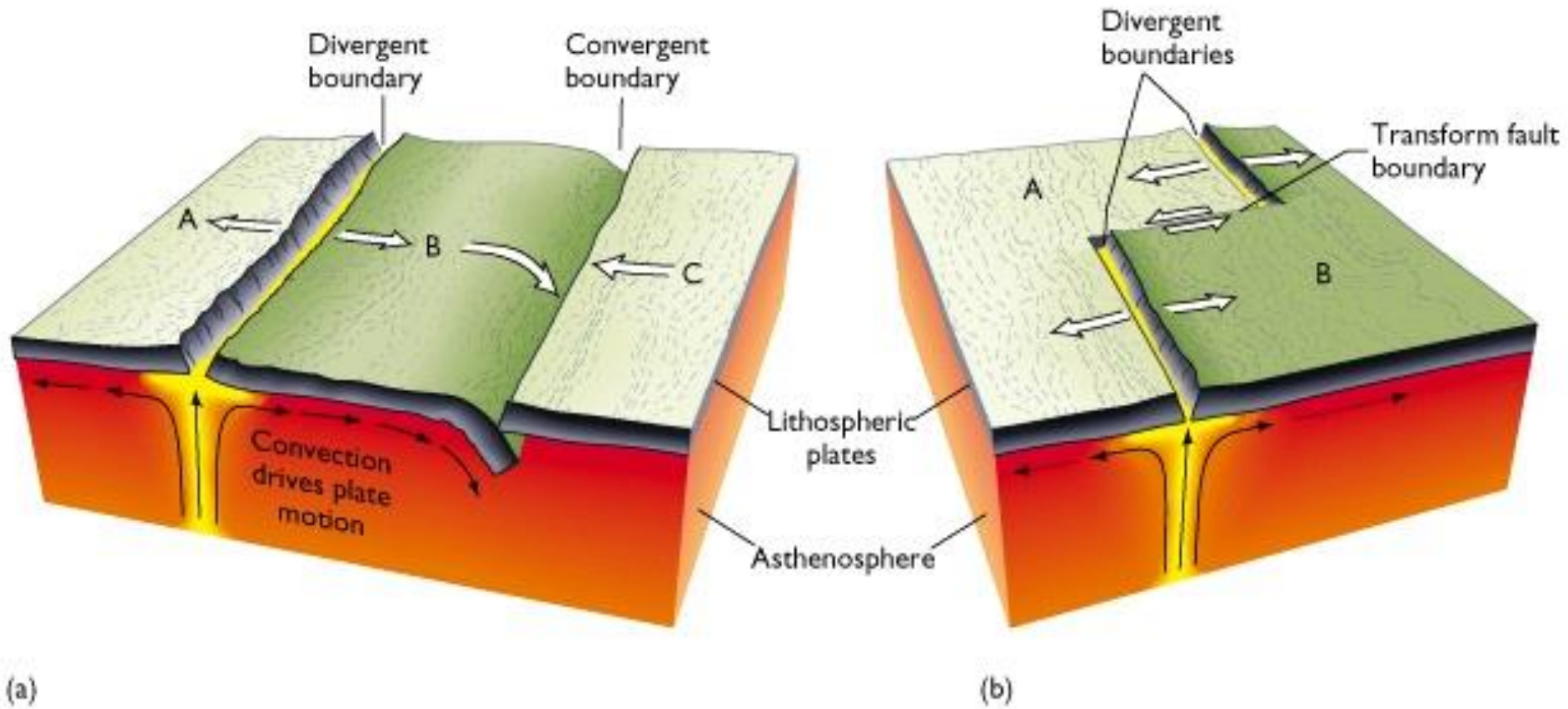
Dynamic Earth

- Plate boundaries

All major interactions among individual plates occurs along their boundaries

1. **Divergent boundary** – two plates move apart, resulting in upwelling of material from the mantle to create new seafloor
2. **Convergent boundary** – two plates move together with subduction of oceanic plates or collision of two continental plates
3. **Transform boundaries** – located where plates grind past each other without either generating new lithosphere or consuming old lithosphere
4. **Changing boundaries** – new plate boundaries are created in response to changes in the forces acting on the lithosphere

Dynamic Earth





Iceland is being
pulled apart as it sits
astride the Mid-
Atlantic Ridge

San Andreas Fault

