Meet Planet Earth

Study Questions

- Describe Earth's internal structure – describe both the compositional and mechanical layers.
- Draw a cross-section through Earth showing the compositional layers (indicate the approximate thickness of these layers) ((Need to know approximate radius of Earth and the radii of various boundaries)
- What is the thickness of oceanic crust? Of continental crust?
- How did the compositional layers develop from an originally homogeneous Earth?
- What are the layers having different physical properties of Earth? Their thicknesses?
- What are the key physical properties that distinguish the inner core, outer core, asthenosphere and lithosphere?
- What are the principal concepts of plate tectonics?
- What is a system? What distinguishes differences between open, closed, and isolated systems?
- Discuss three major Earth cycles and how they interact..
- What is Uniformitaranism? How is it used to better understand Earth?
- What is the difference between a hypothesis and a theory?
- Discuss gradual vs catastrophic geologic processes.

Summary

- Science is a system of learning and understanding. The simplistic "scientific method" is sometimes described: observation, formation of a hypothesis, testing of the hypothesis, formation of a theory, more testing, and, in some instances, formation of a law. A richer context is described
- The Principle of Uniformitarianism states that the internal and external processes operating today have been operating throughout Earthís history.
- Random massive disasters, such as gigantic meteorite impacts, appear to have played important roles in Earthís history. These events cause catastrophic change in Earth's appearance, and to many forms of life, but are not attributed to supernatural forces the way the events of the outdated concept of catastrophism were.
- The planets formed by a two-step process. First, small rocky fragments condensed from a disc-shaped envelope of gas that rotated around the Sun. Then the rocky fragments started accreting into ever larger masses. All formed by about 4.56 billion years ago.

- The heat released by decay of naturally occurring radioactive chemical elements was sufficient, early in Earth's history, to cause a fraction of Earth to melt. Heavy materials sank to the center, and lighter ones rose, giving Earth a compositionally three layered structure: core, mantle, and crust.
- The crust consists of two types: oceanic crust with an average thickness of 8 km and continental crust with an average thickness of about 45 km.
- Earth is layered with respect to its physical properties, in particular strength. The lithosphere, the outer 100-200 km zone of the solid Earth, consists of rock that is strong and relatively rigid. Below the lithosphere, is the asthenosphere, a region where high temperatures make rock weak and easily deformed
- The lithosphere consists of six large and many small plates that slide slowly over the asthenosphere at rates up to 12 cm/yr, as a result of a process called plate tectonics.
- Earth is a closed system. Energy can enter and leave but the amount of matter present is essentially constant.
- Material and energy move back and forth between Earth's open systems in continuing cycles.
- Energy to drive Earth's systems comes from the sun and Earth's internal heat

Introduction

- Other planets in the solar system currently do not have the right chemical and physical mix needed to support humans.
- We have no conclusive evidence yet of life existing elsewhere in the universe – but we are looking!
- Earth is unique and is our "space ship" for life

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Need to keep "life support" systems working!

More than 6 billion people!

- Our activities have direct and indirect consequences
  - Climate
    - Direct impact on us
    - Changes geologic processes
  - Landforms
    - Erosion and depositional
  - Water
    - quantities and quality
  - Hazards

Geology: the science of Earth

- The near space environment
- The solid Earth
- The water, the atmosphere and oceans

What Do Geologists* Do ?

- They seek to understand all processes that operate near, on, or inside Earth

* Earth Scientists (geologist, geochemist, geophysicists, geobiologist, mineralogist, petrologist, sedimentologist, glaciologist, geomorphologist, space physicist, oceanographer, climatologist . . .)

Intrinsically Interdisciplinary

- Chemistry, to understand:
  - Minerals.
  - Dissolved minerals.
  - Minerals resources.
  - Rocks formation.
  - Ground water.
  - Climate

Intrinsically Interdisciplinary

- Physics, to understand:
  - Plate tectonics.
  - Volcanism.
  - Earthquakes.
  - Earth's Magnetic Field
  - Landslides.
  - Near space environment
  - Climate

Intrinsically Interdisciplinary

- Biology, to understand:
  - How life processes integrate with other Earth systems.
  - How life has evolved.
  - Fossils in the rocks
  - Climate

Intrinsically Interdisciplinary

- Atmospheric Science, to understand:
  - Stream flow.
  - Groundwater levels.
  - Climate
- Oceanography, to understand:
  - Seafloor's role in plate tectonics.
  - Shorelines.
  - Climate

Intrinsically Interdisciplinary

- Astronomy.
- Mathematics.
- Computer sciences.
- Economics, to understand how humans employ:
  - Minerals.
  - Energy resources.

The "Cardboard Characterization" of Science

- Make unbiased observations of nature
- Test a hypothesis (by comparing the prediction against new observations).
- Formulate a theory (a generalization about natural phenomena).
- Formulate a law or principle (statements that some natural phenomenon is invariably observed to happen in the same way, and no deviations have ever been observed).
- Continually reexamine the law or principle in the light of new evidence.

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The Nature of Science*

- The Scientific World View
- Scientific Inquiry
- The Scientific Enterprise

**Science for All Americans*: http://www.project2061.org

The Scientific World View

- **Things and events occur in consistent patterns that are comprehensible through careful systematic study**
  - The universe is a vast single system in which the basic rules are the same everywhere
- **Science is a process for producing knowledge that includes careful observations and inventing theories**
  - Testing, improving and occasionally discarding ideas goes on all the time
  - There is no secure complete and absolute truth – just increasingly accurate approximations
  - Scientific knowledge is "durable"
- **There are many matters that cannot be usefully examined in a scientific way**
  - beliefs that cannot be proved or disproved,
  - issues of good and evil

Scientific Inquiry

- **Science has a general reliance on evidence, the use of hypothesis and theories, and the kinds of logic**
  - Bias in observations is generally unavoidable
    - Methods to recognize and overcome biases are necessary
  - Scientific concepts do not emerge automatically from data or analysis
    - Inventing ideas that imagine how the world works is the creative step
  - Scientific ideas should be predictive
  - Authorities are important in science, as elsewhere,
    - But esteemed experts have been wrong many times.
  - When someone comes up with a new or improved idea that explains more phenomena or answers more questions than the previous version, the new one eventually replaces the old

Science Inquiry (cont.)

- **Science methodology is not easily described apart from the context of a particular investigation**
  - No fixed set of steps are always followed,
  - No one path leads unerringly to knowledge
- **Scientific claims are ultimately settled by referring to observations of phenomena**
  - Arguments must conform to principals of logical reasoning
    - May disagree on value of particular observation or particular assumption made – but a clear connection between evidence, assumptions, and conclusions must be made
  - Great value is placed on developing better instruments and techniques of observation

The Scientific Enterprise

- **Science activity is a main feature of the contemporary world**
  - **Science has individual, social, and institutional dimensions.**
  - **Science goes on in many places**
  - **Science inevitably reflects social values and viewpoints**
    - **Research directions are affected by influences within the science culture and as a result of external political forces**
- **Communication is essential and goes on in written and oral forms**
  - **Exposing ones ideas to the criticism of others is important**

The Scientific Enterprise (cont)

- **Science is organized in disciplines**
  - **Advantage in a common structure for organizing research and research findings**
  - **Disadvantage in that they may not match the way the world works.**
- **Most scientists adhere to ethical norms of science including**
  - **General professional behavior**
  - **Watching for possible harm from science investigations**
  - **Watching for possible harm in application of research results**

The Scientific Enterprise (cont)

- **Science can bring information, insights, and analytical skills to issues of public concern**
  - **Scientists are expected to be especially careful in distinguishing fact from interpretation**
  - **Definitive answers are rare**
    - **Issues may be too complex, too little reliable information may be available, or values beyond science may be involved.**
  - **Scientists, like all other people, have biases associated with personal, corporate, institutional, or community interests**
    - **For example, because of their commitment to science, many scientists may be understandably less objective in their beliefs on how science should be funded in comparison to other social needs.**

Nature of Geologic Processes

- Catastrophism
  - A few great upheavals produced the world as we find it
  - Once identified primarily with religious doctrine
- Gradualism
  - Uplift, erosion, transport, deposition are uniformly slow
  - Once identified with “right-thinking” scientists

Uniformitarianism

- Basic processes we observe today have been operating throughout Earth's history.
  - Laws of physics and chemistry have not changed
  - Powerful tool in understanding geologic phenomena
- Does not imply gradualism
  - Geologic events can be truly catastrophic!


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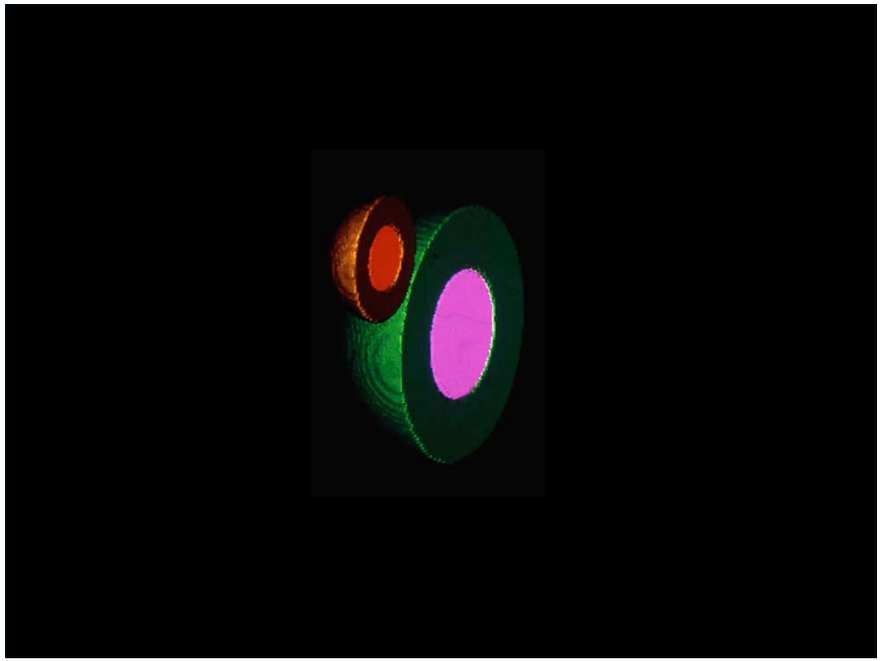

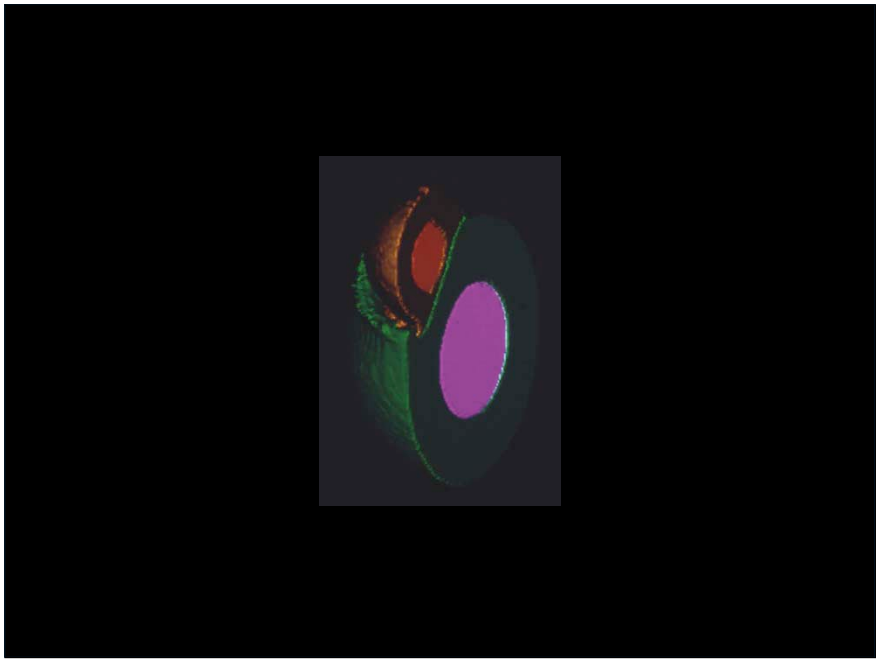

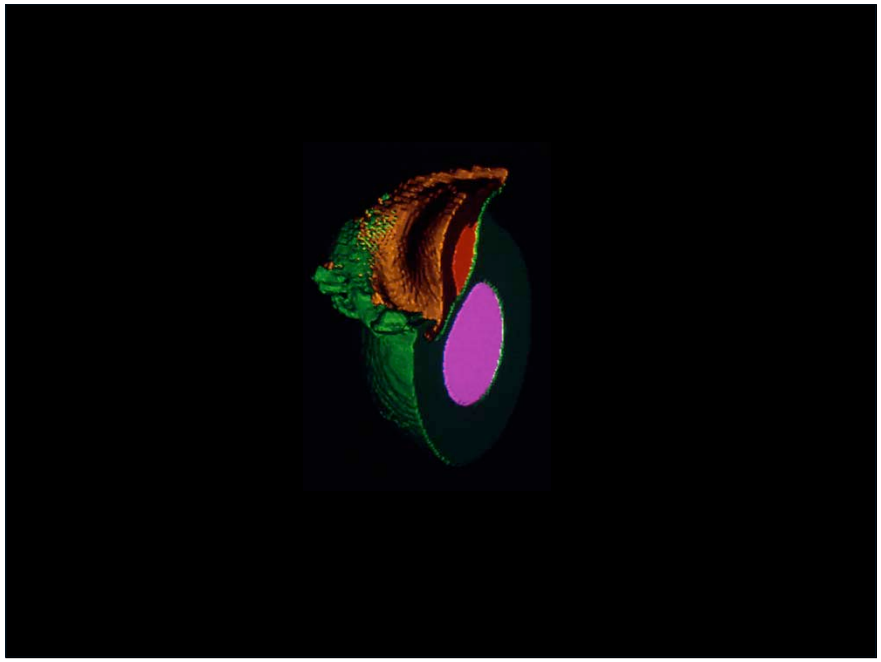

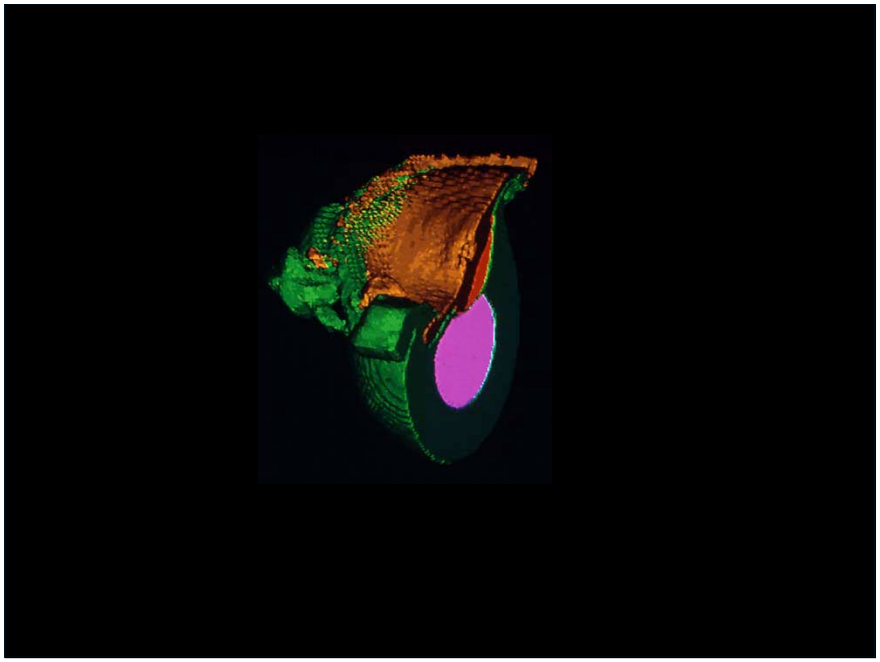

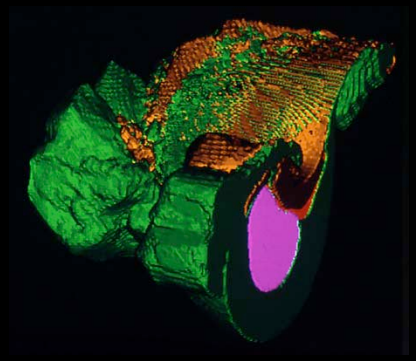

Origin of the Solar System and Earth

- Birth where earlier supernovas, producing a swirling cloud of cosmic gas.
- Center became Sun
- Outer portion of the cosmic gas cloud cooled
  - Condensed first as Chondules
  - Planetary objects formed by accretion
    - Chondules -> Chondrites
    - Chondrites-> planetismals
    - Planetismals -> planets

Earth's Internal Structure

- As Earth grew larger, its temperature increased.
  - Impacts deposited "energy of collision"
  - Radioactive decay also added heat.
- Less-dense molten materials migrate toward the surface.
  - silicon, aluminum, sodium, and potassium
- Denser melted materials sank toward the center.
  - molten iron

The Earth's Interior – Density (compositional) Layering

- Planet Earth has three compositional layers:
  - Dense at center, the core (metallic iron, nickel).
    - 32.5% of mass (90% Fe, 4% Ni, 6% (O,S,C,H,Si, …)
  - Surrounding the core is the mantle.
    - 67% of mass (Mg, Fe, Si) oxide plus small amounts (K,Na,Al, ..)
  - Surrounding the mantle lies the thinnest and outermost layer, the crust.
    - 0.5% of mass (Si-oxide plus K, Na, Al, Mg, Fe, …)

The Earth's Crust

- The crust is not uniform.
  - The oceanic crust on average is about 8 km thick.
    - basalt
  - The continental crust on average is about 45 km thick.
    - Ranges for 25 to 70 km.
    - Granitic - andesite

Physical Properties Layering

- Lithosphere (the "plate" in plate tectonics)
  - High strength "rigid" behavior
  - Variable thickness – 100 km to perhaps more than 200 km
  - Includes crust and part of upper mantle
- Asthenosphere
  - Ductile mantle below Lithosphere
- Mesosphere
  - Term loved by textbook authors
    - not used by active researchers
  - Ductility of lower mantle is less than Asthenosphere

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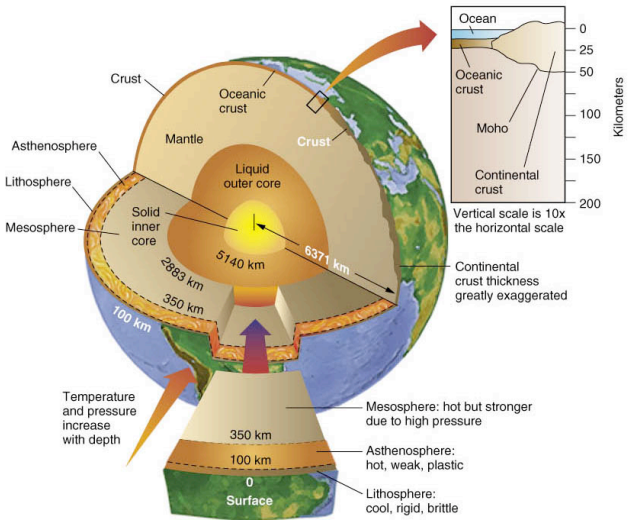


Figure 1.13

Plate Tectonics – The Basics

- Earth's Lithosphere is broken into about a dozen large pieces
- Pieces are free to move horizontally
  - Move apart – divergence – spreading centers
  - Move together – convergence – subduction zones
  - Slide side-by-side – transform
- Movement driven by heat loss from interior
  - Mantle undergoes convection
- Most geologic "action" occurs at boundaries

Plate Tectonics Explains Many Phenomena

- Location and types of Earthquakes.
- Location and types of Volcanos.
- Mountain-building.
- History of sea level.
- Large climate changes in past
- Location of continents in past

The System Concept

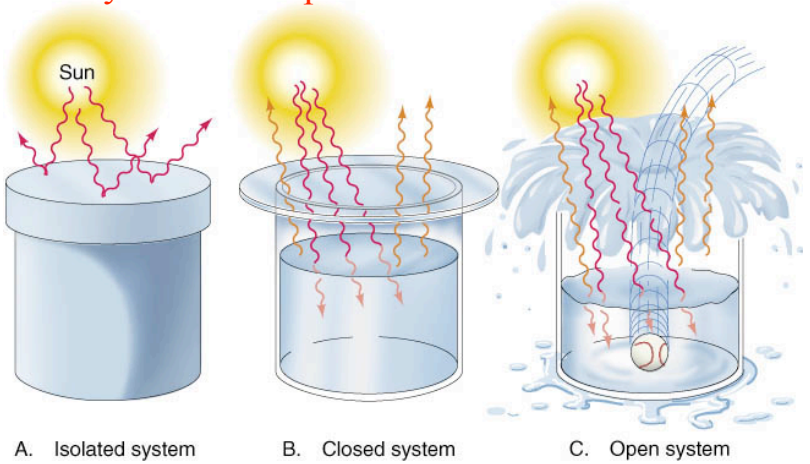


Figure 1.14

Cycles

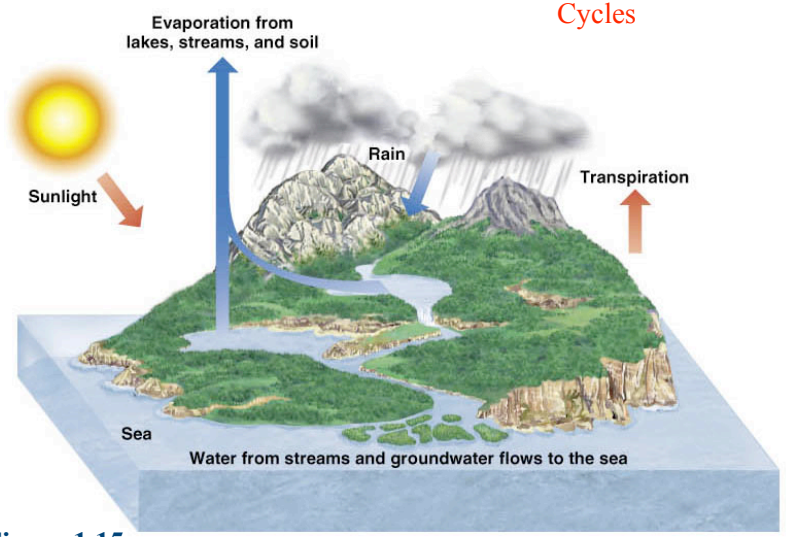
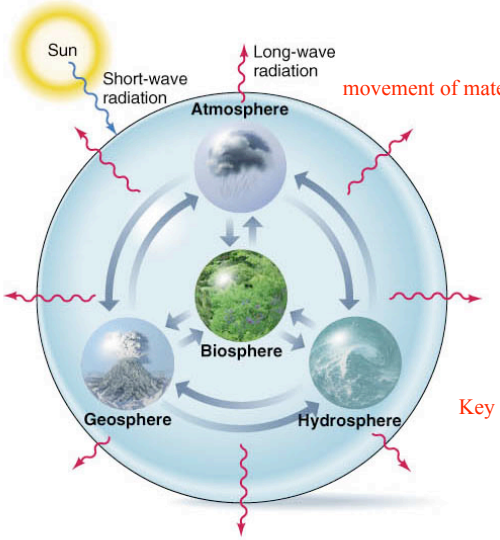


Figure 1.15



movement of materials is continuous

Key aspects to cycles:
The reservoirs.
The flows, or fluxes
The speed of movement.

Figure 1.16

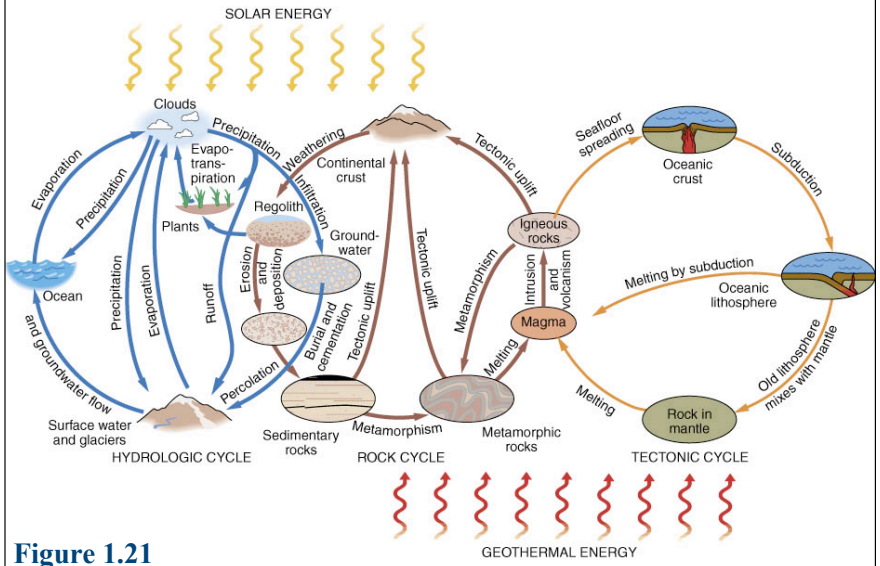


Figure 1.21

Changes Caused By Human Activities

- Burning petroleum and coal, which increases the greenhouse effect.
- Intensive human activities (farming, development, mining, forest clearing) which have grave impact on land surfaces, soils, ground and surface water.
- Production and release of gases containing chlorine, which destroys ozone.
- Civilizations are increasingly in “harms way”