INSTRUCTOR RESOURCE MANUAL

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Earth: An Introduction to Physical Geology

Eleventh Edition

Tarbuck • Lutgens • Tasa

Contents

AN INTRODUCTION TO GEOLOGY 1

INTRODUCTION

An Introduction to Geology covers the fundamental ideas and concepts of geologic study. Fundamental concepts of historical geology, including catastrophism, uniformitarianism, and geologic time, provide a context to the study of geology. A discussion of scientific inquiry aids in understanding how geologic processes and materials are studied and understood. The chapter provides a brief discussion of Earth's spheres, including the hydrosphere, atmosphere, biosphere, and geosphere, and discusses Earth systems science as a means of understanding the interconnectedness of these spheres. The chapter next discusses the formation of the solar system Earth and the fundamental concepts of density and buoyancy in understanding Earth structure. This leads to a discussion of Earth's layering, and the rock cycle operating at and beneath Earth's surface. The chapter ends with a discussion of the major physical features of the Earth's surface, including those of the continents and ocean basins.

CHAPTER OUTLINE

1. Geology: The Science of Earth
- a. Geology is the science that works to understand Earth
    - i. Divided into many areas of specialization
    - ii. Requires an understanding and application of knowledge and principles from physics, chemistry, and biology
    - iii. Seeks to expand our knowledge of the natural world and our place in it
- b. Physical Geology
    - i. Examines the materials composing Earth and seeks to understand the many processes that operate beneath and upon its surface
- c. Historical Geology
    - i. Attempts to understand the origin of Earth and its development through time
- d. Geology, People, and the Environment
    - i. The problems and issues addressed by geology are of practical value to people
    - ii. Natural hazards—natural Earth processes that negatively interact with humans
        1. volcanoes, floods, tsunami, earthquakes, and landslides
        2. caused by urbanization
    - iii. Resources—natural Earth materials utilized by humans
        1. water and soil, metallic and nonmetallic minerals, and energy
    - iv. Basic geologic knowledge and principles are needed to understand environmental problems

2. The Development of Geology
- a. Begins with writings of Greeks, more than 2300 years ago

i. Aristotle
   1. influential philosopher
   2. Inaccurate explanations about the natural world
   3. Based on keen observations and experiments
   4. Continued to be viewed as authoritative for many centuries

b. Post 1500s—Catastrophism
   1. In 1600s, James Ussher calculated that Earth was only a few thousand years old (began 4004 BC)
      a. This number earned widespread acceptance in science and religion
   2. Led to idea that Earth's landscapes had been shaped primarily by great catastrophes
      a. Produced by sudden and often worldwide disasters produced by unknowable causes that no longer operate
   3. An attempt to fit the rates of Earth processes to the then-current ideas on the age of Earth

c. Birth of Modern Geology—Uniformitarianism
   i. *Physical, chemical, and biological laws that operate today have also operated in the geologic past*
   ii. Commonly stated as *the present is the key to the past*
   iii. Forces and processes that we observe presently shaping our planet have been at work for a very long time
   iv. Hutton's *Theory of the Earth* persuasively argued that forces that appear small could, over long spans of time, produce effects
      1. Carefully cited verifiable observations to support his ideas

d. Geology Today
   i. Present gives us insight into the past and that the physical, chemical, and biological laws that govern geological processes remain unchanging through time
   ii. Does not suggest that they always had the same relative importance or that they operated at precisely the same rate
   iii. Some important geologic processes are not currently observable, but evidence that they occur is well established
   iv. Grand Canyon provides a good example (Figure 1.5)

e. Geologic Time
   i. Earth has a very long and complex history
   ii. Early time scales placed the events of Earth history in order without knowing how long ago, in years, they occurred
   iii. Today, radioactivity allows us to accurately determine numerical dates for rocks that represent important events in Earth's distant past
   iv. Today, the age of Earth is put at about 4.6 billion years

3. The Nature of Scientific Inquiry

a. Science is a process of making careful observations and creating explanation to produce knowledge about the natural world

    i. Assumption: the natural world behaves in a consistent and predictable manner that is comprehensible through careful, systematic study
    ii. Goal: discover the underlying patterns in nature and then use this knowledge to make predictions about what should or should not be expected, given certain facts or circumstances

b. Development of new scientific knowledge involves some basic logical processes that are universally accepted
    i. Hypothesis—a tentative (or untested) explanation of an observation or data
        1. Generally, scientists formulate more than one
    ii. Testing and analysis—predictions are made based on the hypothesis being considered and the predictions are tested
        1. If a hypothesis cannot be tested, it is not scientifically useful
        2. Those hypotheses that fail rigorous testing are ultimately discarded
    iii. Theory—well-tested and widely accepted view that the scientific community agrees best explains certain observable facts

c. Scientific Methods
    i. Process of gathering facts through observations and formulating scientific hypotheses and theories
    ii. Not a standard recipe that scientists apply in a routine manner
        1. An endeavor that involves creativity and insight
    iii. Many scientific investigations involve the following:
        1. A question is raised about the natural world
        2. Scientific data are collected that relate to the question
        3. Questions are posed that relate to the data and one or more working hypotheses are developed that may answer these questions
        4. Observations and experiments are developed to test the hypotheses
        5. The hypotheses are accepted, modified, or rejected based on extensive testing
        6. Data and results are shared with the scientific community for critical examination and further testing.
    iv. Other scientific discoveries may result from purely theoretical ideas found using models or simulations

d. Plate Tectonics and Scientific Inquiry
    i. Early 20th century—continental drift
        1. The idea that the continents moved about the face of the planet
        2. Contradicted the established view that the continents and ocean basins are permanent and stationary features
    ii. 50 years later—Plate Tectonics
        1. Enough data were gathered to transform this controversial hypothesis

2. A sound theory that wove together the basic processes known to operate on Earth
3. Provided geologists with the first comprehensive model of Earth's internal workings.

4. Earth's Spheres

a. Earth can be thought of as consisting of four major spheres: the hydrosphere, atmosphere, geosphere, and biosphere
   i. Hydrosphere
      1. Dynamic mass of water that is continually on the move
      2. Evaporating from the oceans to the atmosphere, precipitating to the land, and running back to the ocean again
      3. Ocean—71 percent of Earth's surface, and 97 percent of Earth's water
      4. Also glaciers, streams, groundwater
   ii. Atmosphere
      1. Earth's thin gaseous envelope
      2. Provides the air that we breathe
      3. Protects us from the Sun's intense heat and dangerous ultraviolet radiation
      4. Energy exchanges between the atmosphere and Earth's surface produce weather and climate
   iii. Biosphere
      1. All life on Earth
      2. Most life on land is also concentrated near the surface
      3. Life forms help maintain and alter the physical environment
   iv. Geosphere
      1. The solid Earth beneath the atmosphere and oceans
      2. Extends from the surface to the center of the planet, a depth of nearly 6400 kilometers

b. Examples of interactions of all spheres: Soil
   i. The thin veneer of material at Earth's surface
   ii. Supports the growth of plants
   iii. May be thought of as part of all four spheres
      1. Weathered rock debris (geosphere)
      2. Organic matter from decayed plant and animal life (biosphere)
      3. Rock debris is the product of weathering processes that require air (atmosphere) and water (hydrosphere).
      4. Air and water also occupy the open spaces between the solid particles.

5. Earth System

a. System—a group of interacting, or interdependent, parts that form a complex whole
b. The spheres of Earth interact to produce a complex and continuously interacting whole (Earth system)

i. In order to more fully understand our planet, we must learn how its individual components (land, water, air, and life forms) are interconnected
ii. Earth system science attempts to integrate the knowledge of several academic fields using interdisciplinary approach

c. The Earth system has a nearly endless array of subsystems in which matter is recycled over and over again
   i. Examples: Hydrologic cycle, carbon cycle, rock cycle
   ii. Parts of the Earth system are linked so that a change in one part can produce changes in any or all of the other parts
   iii. Characterized by processes that vary on spatial scales from fractions of millimeters to thousands of kilometers
d. Earth system is powered by energy from two sources
   i. Sun—drives weather and climate, ocean circulation and erosional processes
   ii. Earth's internal heat—power the internal processes that produce volcanoes, earthquakes, and mountains.
e. Humans are part of the Earth system and our actions produce changes in all of the other parts

6. Evolution of Earth
   a. Big Bang—13.7 billion years ago, formed the universe
   b. Formation of solar system
      i. Nebular hypothesis—Solar system evolved from an enormous rotating cloud called the solar nebula
         1. composed mostly of hydrogen and helium
   c. About 5 billion years ago, the nebula began to contract
      i. Assumed a flat, disk shape with the protosun (pre-Sun) at the center
   d. Inner planets form
      i. Formed from metallic and rocky clumps of substances with high melting points
         1. The elements of which the rock-forming minerals are composed—silicon, calcium, sodium
      ii. Repeated collisions caused these masses to coalesce into larger asteroid-size bodies, called *planetesimals*
      iii. Mercury, Venus, Earth, and Mars
      iv. Rocky and metallic pieces that remained in orbit are called *meteorites*
   e. Outer planets develop
      i. Larger outer planets began forming from fragments with a high percentage of ices of water, carbon dioxide, ammonia, and methane
      ii. Jupiter, Saturn, Uranus, and Neptune

7. Formation of Earth's layered structure
   a. As Earth formed, the decay of radioactive elements and heat from high-velocity impacts caused the temperature to increase
      i. Iron and nickel began to melt and sink toward the center

- ii. Lighter rocky components floated outward, toward the surface
- iii. Process is called chemical differentiation

b. Gaseous material escaped from Earth's interior to produce the primitive atmosphere

c. Modern continental crust formed gradually over the last 4 billion years

8. Earth's Internal Structure

a. Earth's internal layers can be defined by chemical composition, and/or physical properties

b. Layers defined by composition

- i. Crust
  1. Thin, rocky outer skin
  2. Two divisions
     - a. Oceanic crust
       - i. Seven kilometers (5 miles thick)
       - ii. Composed of dark igneous rocks called basalt
     - b. Continental crust
       - i. Averages 35–40 kilometers (25 miles) thick
       - ii. Composition consists of many rock types
       - iii. Upper crust has an average composition of a granitic rock
       - iv. Lower crust is more akin to basalt
     - c. Continental crust rocks are less dense and older than oceanic crust rocks
- ii. Mantle
  1. More than 82 percent of Earth's volume
  2. Solid, rocky shell
  3. Extends to a depth of 2900 kilometers (1800 miles)
  4. Dominant rock in the uppermost mantle is peridotite
- iii. Core
  1. Thought to be composed of an iron-nickel alloy with minor amounts of oxygen, silicon, and sulfur
  2. Due to the extreme pressure found in the core, the density is nearly 11 g/cm^3

9. Layers defined by physical properties

a. Temperature, pressure, and density gradually increase with depth in Earth's interior.

b. Changes in temperature and pressure affect the physical properties

c. Hence, the mechanical behavior of Earth materials

d. Five main layers of Earth based on physical properties and hence mechanical strength.

- i. Lithosphere
  1. Consists of the crust and uppermost mantle
  2. Relatively cool, rigid shell

        3. Averages about 100 kilometers in thickness, but may be 250 kilometers or more thick below the older portions of the continents
        4. Within the ocean basins it is only a few kilometers thick
    ii. Asthenosphere (“weak sphere”)
        1. Beneath the lithosphere, in the upper mantle
        2. Small amount of melting in the top portion
        3. Lithosphere is mechanically detached and is able to move independently of the asthenosphere
    iii. Mesosphere (or lower mantle)
        1. Between 660 and 2900 kilometers
        2. Rocks are rigid but capable of very gradual flow
    iv. Core
        1. Outer core
            a. A liquid layer
            b. Convective flow of metallic iron generates Earth’s magnetic field
        2. Inner core
            a. Strong due to immense pressure near center of Earth
            b. Solid

10. The Rock Cycle
- a. The loop that involves the processes by which one rock changes to another; powered by the Sun and Earth’s internal heat
- b. Processes
    - i. Rocks continuously change from one form to another due to natural earth processes
    - ii. Crystallization—cooling and solidification of magma
    - iii. Weathering—disintegration and decomposition of rocks at the surface
    - iv. Lithification—conversion of loose sediment to rock
    - v. Heat and pressure—act to change minerals within a rock or melt the rock
- c. Rock Types
    - i. Igneous—rocks formed from cooling and crystallization of molten material
    - ii. Metamorphic—rocks formed from subjecting pre-existing rocks to heat and pressure
    - iii. Sedimentary—rocks formed from the weathering and erosion of pre-existing rock into sediment, which is then compacted or lithified into rock
- d. Alternate paths
    - i. For example,, igneous rocks become metamorphic rocks
    - ii. For example, metamorphic and sedimentary rocks become sediment

11. The face of Earth
- a. Earth’s surface—continents and oceans

b. Significant difference between the continents and ocean basins is their relative levels
c. Continents
   i. Most prominent features are linear mountain belts
      1. Not randomly distributed
      2. Two zones
         a. Circum-Pacific belt surrounding the Pacific Ocean
         b. The area that extends eastward from the Alps through Iran and the Himalayas, and then dips southward into Indonesia
   ii. The Stable Interior
      1. Also known as a craton
      2. Shields are expansive, flat regions on the craton composed of deformed crystalline rocks
      3. Other flat areas where the shields are covered by a thin veneer of sedimentary rocks are called stable platforms
d. Ocean basins
   i. Continental margins
      1. Continental shelf, a gently sloping platform of continental material, extends seaward from the shore
      2. Continental slope, a steep drop-off at the outer edge of the continental shelf, marks the boundary between the continents and the deep-ocean basin
   ii. Deep-ocean basins
      1. Located between the continental margins and oceanic ridges
      2. Flat, featureless areas are known as the abyssal plains
      3. Oceanic trenches are long, narrow canyons on the ocean floor
         a. Some trenches are located adjacent to young mountains that flank the continents while others parallel linear island chains called volcanic arcs
      4. Seamounts are submerged volcanic structures on the ocean floor
   iii. Ocean ridge system—sthe most prominent topographic feature on Earth
      1. Continuous belt that winds for more than 70,000 kilometers around the globe
      2. Composed of igneous rock that has been fractured and uplifted

LEARNING OBJECTIVES/FOCUS ON CONCEPTS

Each statement represents the primary learning objective for the corresponding major heading within the chapter. After completing the chapter, students should be able to:

1.1 Distinguish between physical and historical geology, and describe the connections between people and geology.

1.2 Summarize early and modern views on how change occurs on Earth and relate them to the prevailing ideas on the age of Earth.

1.3 Discuss the nature of scientific inquiry, including the construction of hypotheses and the development of theories.

1.4 List and describe Earth's four major spheres.

1.5 Define *system* and explain why Earth is considered to be a system.

1.6 Outline the stages in the formation of our solar system.

1.7 Describe Earth's internal structure.

1.8 List and describe the major features of the continents and ocean basins.

1.9 Sketch, label, and explain the rock cycle.

TEACHING STRATEGIES

Introduce the Science of Geology: The first chapter of the book is a good time to discuss what a geologist does, and the science of geology. This activity helps students to know their own role and interest in geology, while allowing the instructor to review writing styles of the class.

- Calibrated Peer Review Activity—"Why Study Geology": http://serc.carleton.edu/introgeo/peerreview/examples/why_study_geo.html

Muddiest Point: In the last 5 minutes of class, have students jot down the points that were most confusing from the day's lecture, and what questions they still have. Or provide a "self-guided" muddiest point exercise, using the "CRS" PowerPoints and website questions for this chapter. Review the answers, and cover the unclear topics in a podcast to the class or at the beginning of the next lecture.

The following are fundamental ideas from this chapter that students have the most difficulty grasping.

A. Nature of Science

a. Students come to an intro-level science course thinking that science is the objective accumulation of facts and science is always done following the exact steps of the scientific method. Getting students to think of science as an inquiry process is difficult, and should be reiterated throughout the semester. The fundamental concept of scientific inquiry can be explained to your students with this chapter, as the foundation of the remaining chapters. Urge your students to continuously think about "How do we know what we know?"

b. Guided Reading of a Scientific Article: http://serc.carleton.edu/NAGTWorkshops/structure/activities/47021.html

c. How many sand grains on a beach? http://serc.carleton.edu/quantskills/activities/14846.html
d. Thinking Scientifically: http://serc.carleton.edu/introgeo/indoorlabs/examples/21805.html

B. Geologic Time

a. Geologic time is difficult for a student to understand. Ask students to think about what is "old" to them. They will say things like grandma, the United States, a car, etc. Ask them what is "ancient." They will likely think of things like redwood trees, Indiana artifacts, the Bible, etc. This can lead into a discussion of what is young and old to geologists. Cite specific Earth events and geologic events from your own region. Then, have students calculate how long it would take to count to 4.6 billion (the answer is in the text, but this is a useful exercise in unit conversion).
b. Big Numbers and Scientific Notation. http://serc.carleton.edu/quantskills/methods/quantlit/BigNumbers.html
c. How big is a billion? http://serc.carleton.edu/quantskills/activities/UndBigNos.html

C. Earth Structure

a. Many students believe the entire Earth is molten beneath the surface (or even hollow—thanks, Hollywood!). Students have difficulty visualizing the interior structure of the Earth, so animations are helpful in helping them make these visualizations. Also provide alternative readings on HOW we know the structure and composition of the inside of the Earth.
b. USGS "The Interior of the Earth": http://pubs.usgs.gov/gip/interior/
c. Good imagery and models: http://crack.seismo.unr.edu/ftp/pub/louie/class/100/interior.html
d. Scientific Evidence for Structure of Earth's Interior: http://www.columbia.edu/~vjd1/earth_int.htm

D. Humans and Earth

a. Students often think that humans cannot affect Earth processes, and therefore our actions are insignificant when thinking about Earth as a system. This concept should be addressed throughout the course, and in more detail in an Environmental Geology course. Here, when discussing Earth as a system, it is important to provide a few examples of how humans affect Earth processes.
b. A few articles to help you think about this:
   i. http://geology.geoscienceworld.org/content/33/3/161.abstract
   ii. http://www.sciencemag.org/content/277/5325/494.abstract
c. And, a fun debate for class: Have humans created a new geologic age? http://www.newscientist.com/blog/environment/2008/01/have-humans-created-new-geological.html

TEACHER RESOURCES

Teaching 100-level Geoscience Courses

- http://serc.carleton.edu/teachearth/site_guides/intro_course.html
- http://serc.carleton.edu/NAGTWorkshops/intro/motivation.html
- http://serc.carleton.edu/NAGTWorkshops/intro/large_classes.html

Scientific Inquiry and Geosciences

- McLelland, Christine V., "The Nature of Science and the Scientific Method," The Geological Society of America, August 2006. http://www.geosociety.org/educate/NatureScience.pdf
- What do Geoscientists do?
  - http://www.agiweb.org/workforce/brochure.html
  - http://geology.com/articles/what-is-geology.shtml
  - http://www.bls.gov/ooh/Life-Physical-and-Social-Science/Geoscientists.htm

Geologic Time

- Graphical Representation: http://pubs.usgs.gov/gip/geotime/time.html
- Clock of Eras: http://www.fossils-facts-and-finds.com/clock_of_eras.html
- USGS and NPS "What is Geologic Time?": http://www2.nature.nps.gov/geology/usgsnps/gtime/gtime1.html
- Other visualizations: http://serc.carleton.edu/NAGTWorkshops/time/teaching_visualizations.html
- This activity can help students visualize the span of geologic time: http://www.geologyclass.org/Geologic%20Time%20Scale%20Activity.htm
- This website gives you specific information, pictures, and histories of each geologic time period: http://www.ucmp.berkeley.edu/help/timeform.html
- Geological Society of America Geologic Time Scale: http://www.geosociety.org/science/timescale/

Cycles on Earth:

- Rock Cycle: http://ansatte.uit.no/kku000/webgeology/webgeology_files/english/rocks.html
- Water Cycle: http://www.montereyinstitute.org/noaa/lesson07.html
- Carbon Cycle: http://earthobservatory.nasa.gov/Features/CarbonCycle/
- Plate Tectonics: http://www2.nature.nps.gov/geology/usgsnps/animate/pltecan.html
- A kids website, but a good introduction to cycles later covered: http://www.eo.ucar.edu/kids/green/cycles1.htm

ANSWERS TO QUESTIONS IN THE CHAPTER:

CONCEPT CHECKS

1.1

1. *Physical geology is the study of materials composing the Earth (minerals, rocks, water, etc.) and the processes that operate upon and below Earth's surface (plate tectonics, rock formation, deformation, erosion, etc.). Historical geology aims to understand the origin of the Earth and its development through time. This study establishes an orderly chronological arrangement of events and changes of the geologic past by study of the origin of rocks, the movements of plates over time, and the occurrence of ancient environments and life forms as displayed in the geologic record. These two areas of study are subdivided into many more areas of specialization.*
2. *Geologic hazards are natural Earth processes that adversely affect humans. Examples of geologic hazards include earthquakes, volcanic eruptions, floods, tsunami, and landslides. Humans can also exacerbate natural Earth processes, creating hazards, by interfering with natural processes. Examples include the increased flooding hazards created by the clearing of forests, building cities, and constructing dams.*
3. *Earth resources, formed by Earth processes, have tremendous value to humans. These resources include water, soil, metallic and nonmetallic minerals, and energy. The extraction and use of these resources have many environmental impacts.*

1.2

1. *Aristotle was a Greek philosopher whose writings influenced early understanding of the Earth. Unfortunately, Aristotle's ideas were not based on study and observation, but simply his own opinions of how the natural world worked. These ideas were viewed as authoritative explanations for many centuries, slowing the progress of study based on observations, until Renaissance thought pushed more detailed study of the Earth.*
2. *Catastrophism viewed the Earth as being shaped by great catastrophes – sudden and worldwide disasters produced by unknowable processes that no longer operate. Catastrophism was based on the idea that Earth formed in 4004 BC as calculated by biblical scholar James Ussher in 1660. Conversely, uniformitarianism (now a fundamental concept of geology) views Earth processes as happening over very long time periods, and those processes that we see operating today also operated in the geologic past. The common idea of uniformitarianism is "the present is the key to the past." This concept understands that Earth is much older than though by catastrophism, and processes that operate continually on and beneath its surface created (and continue to create) the features we see.*

3. *Today, the age of Earth is put at about 4.6 billion years. This age is based on scientific study of the radioactivity of rocks, as will be discussed in Chapter 9.*
4. *An understanding of geologic time is essential to geologic study because many processes studied are so gradual that vast spans of time must pass before noticeable and significant changes occur. For example, the rocks of the Grand Canyon (Figure 1.5) were created over millions of years, and it took many more millions of years for the Colorado River to erode down through these rocks to the display we see today.*

1.3

1. *A scientific hypothesis is a tentative, untested explanation of a natural phenomenon. Generally, scientists formulate more than one hypothesis to explain their observations. A fundamental caveat of a hypothesis is that it must be testable (able to pass objective testing and analysis); if it cannot be tested, it is not scientifically useful. Hypotheses may be accepted when evidence demonstrates that they are correct, but also may be rejected when they fail rigorous testing. The Earth-centered model of the universe is an example of a hypothesis that, once tested, was rejected as an explanation of the orientation of our planet in the solar system.*

   A scientific theory is a well-tested hypothesis that has gone through extensive testing and scrutiny. It is a well-tested and widely accepted view that the scientific community agrees best explains a natural phenomenon. Theories generally include several well-tested, accepted hypotheses to explain a larger scale process or phenomenon on Earth. An example of a theory is the Theory of Plate Tectonics, which will be discussed in Chapter 2.
2. *The scientific method is the process by which researchers gather facts through observations and formulate scientific hypotheses and theories. Although this method does not always follow a fixed path, it does involve: (1) a question about the natural world, (2) data collection related to that question, (3) formulation of one or more hypothesis to explain the question and data, (4) observation and experiments to test the hypothesis, (4) the acceptation, modification or rejection of the hypothesis based on extensive testing, and (5) sharing data and results with the scientific community for further testing and critical examination.*
3. *Continental drift was a hypothesis of the early 20th century stating that continents moved (drifted) about the face of the planet into their current configurations. This hypothesis was based on observations at the surface of Earth, but was not tested. As more data was collected, and technology progressed to allow more detailed study of the Earth's surface, this hypothesis transformed into the well-tested, widely accepted Theory of Plate Tectonics, a theory that links the surface orientation of the continents with the inner workings of Earth.*

1.4

1. *The hydrosphere is the dynamic mass of water at Earth's surface, including water in the oceans, atmosphere, lakes and rivers, glacial ice, and groundwater. Water moves about the*

hydrosphere via the water cycle through processes such as evaporation, transpiration, runoff, precipitation, and infiltration.

The atmosphere is the gaseous layer surrounding Earth's surface. This layer comprises the air we breathe, protects Earth from harmful ultraviolet radiation, and creates the weather and climate we experience at the surface.

The biosphere is all life on Earth. The biosphere includes plants and animals living on and above Earth's surface, within the oceans, and underground.

The geosphere is the solid earth extending from the surface to the center (core) of Earth including both consolidated (rock) and unconsolidated (sediment) earth material. The geosphere includes rock and sediment at the surface, bedrock beneath and at the surface, and the materials making up the layers deep within the Earth.

2. *Ninety percent of Earth's atmosphere is located within 16 km (10 mi) of the surface. Compared to the geosphere, which comprises the entire inner Earth to a depth of 6400 km (4000 mi), the atmosphere is an extremely thin veneer on the surface of the Earth.*
3. *Earth's oceans cover 71 percent of its surface and represent 97 percent of Earth's water supply.*
4. *Because soil contains parts of all Earth's spheres, it can be thought of as a part of all four spheres. Soil is a mixture of weathered rock debris (geosphere), organic matter from decayed plants and animals (biosphere), air (atmosphere), and water (hydrosphere).*

1.5

1. *A system is a group of interacting, or interdependent, parts forming a complex whole. The Earth system is comprised of individual components such as land, water, air, and life (Earth's spheres) that are interconnected and interact to create the processes we see at the surface. Examples of systems operating on Earth include the rock cycle (the recycling of rock from one form to another), the hydrologic cycle (the movement of water about and beneath the surface), and the carbon cycle (the exchange of carbon between the air, life, and rocks).*

2. *The Earth system is powered by energy from the Sun and from heat energy generated from Earth's interior. Energy from the Sun drives processes in the atmosphere and hydrosphere such as weather, climate, ocean circulation, and erosional processes. Energy from the Earth's interior is continuously generated by radioactive decay and powers internal Earth processes such as volcanism, earthquakes, and mountain-building.*

3. *Increased rainfall in an area, a process of the atmosphere and hydrosphere, can affect other Earth systems. The increased rainfall can affect the geosphere by triggering massive debris flows (movements of unconsolidated earth materials downslope) and flooding (running water overflowing natural channels) that erode the surface. These events in turn affect humans, plants and animals by displacing the solid earth, impacting homes and businesses and altering ecosystems.*

EYE ON EARTH

EOE #1 Questions

The lowest layers are oldest, and the upper layers are youngest.

EOE #2 Questions

The rocks here made from sediments that are deposited in horizontal layers by rivers, waves, wind and glaciers. If these rocks formed in layers, the bottom layer must have been laid down first, then the next, then the next, and so on.

EOE #3 Questions

1. *Using the curved line on Figure 1.12, the air pressure at 10 km (6.2 miles) is approximately 250 mb.*
2. *To determine this answer, subtract 250 mb from 1000 mb and divide by 1000 mb. Multiply your answer by 100 to get a percent: 1000 mb – 250 mb = 750 mb / 1000 mb = 0.75 x 100 = 75% of the atmosphere is below the jet.*

GIVE IT SOME THOUGHT

1. *To determine this answer, you should divide the amount of human history by all of geologic time (rounded to 5 billion).*

   5000 years / 5,000,000,000 years = 0.000001 = 1.0×10^{-6}

   To make this a percentage, take the answer times 100.

   0.000001 x 100 = 0.0001%

   Therefore, recorded human history of 5000 years is 0.0001% of all geologic time.

2. *Hypotheses for this observation include:*
   a) *The switch is not working.*

b) The bulb in the light is not working (needs to be replaced).
c) The electricity in the room is not working.

Once we have formulated our hypotheses, we should begin testing them. For our first hypothesis and our last hypothesis, we could have an electrician test the power at the switch and in the room to see if it is functioning properly. For our second hypothesis, we might try to replace the lightbulb with a new one, and retry the switch.

3. *Figures 1.2 a and b and Figure 1.8 a and b demonstrate ways scientific data are gathered.*

4.

*a) One breath at sea level is 1000 mb of pressure; we can assume this means 100% atmosphere at sea level. At the top of Mount Everest, Figure 1.12 shows that pressure is 314 mb; this is roughly 31% atmosphere at the top of Mount Everest. Therefore, we would need to take about 3.2 breaths (31% * 3.2 = 99.82%) to equal one breath at sea level.*
*b) Using Figure 1.12, we see that the pressure at 12 km is 200 mb. To determine this answer, subtract 200 mb from 1000 mb and divide by 1000 mb to get the fraction of air at this altitude. Multiply your answer by 100 to get a percent: 1000 mb – 200 mb = 800 mb / 1000 mb = 0.80 * 100 = 80% of the atmosphere is below a jet traveling at 12 km altitude.*

5. *See labeled figure below for numbers:*

1) Evaporation at Earth's surface provides water to the atmosphere.
2) Plants at the surface extract CO_2 from the atmosphere as part of their photosynthetic cycle.
3) Running water is a strong erosional agent of rocks and sediments at Earth's surface.
4) Plants and animals act to break down Earth materials and add nutrients and organic matter to soils.
5) Wind is both an erosional and depositional agent in arid and coastal regions.

6. *In this photo, we see the interactions of the atmosphere, hydrosphere, and geospheres. The atmosphere contained the water vapor that fell to Earth as rain, thus creating an excess of water (hydrosphere) on the hillside (geosphere). This water saturated the earth materials (geosphere) of the hillside and they were set into motion when their stabilizing forces were overcome by gravitational forces. We might also say that the biosphere was involved, as plants, animals, and humans were likely affected by this mass movement.*

7. *Jupiter:*

Figure 3 on page 23 tells us that 1 AU equals150 million (150,000,000) kilometers. To determine the number of kilometers between Earth and Jupiter:

5.3 AU x 150,000,000 km = 795,000,000 kilometers

If we are traveling 1000km/hour (kph), to determine how long it would take to travel 795 km:

795,000,000 km / 1000 kph = 795,000 hours

We can convert this to days:

795,000 hours / 24 hours per day = 33,125 days

It would take us 33, 125 days to reach Jupiter in a jet plane!

Neptune:

We do the same calculations for Neptune, using 30 AU instead. Here, we get an answer of 4,500,000 hours, or 187,500 days.

8. *All rock types, once exposed at the surface, can undergo weathering and erosion to become sediment. The resulting sediment will eventually be transformed into sedimentary rock at the surface, thus accounting for a large percentage of all rocks.*