**Chapter 1:**

**Understanding Earth: A Dynamic and Evolving Planet**

**Chapter Outline**

1.1 Introduction

1.2 What Is Geology?

1.3 Geology and the Formulation of Theories

1.4 How Does Geology Relate to the Human Experience?

1.5 How Does Geology Affect Our Everyday Lives?

1.6 Global Geologic and Environmental Issues Facing Humankind

1.7 Origin of the Universe and Solar System, and Earth’s Place in Them

*GEO-INSIGHT 1.1:* Mars—The “Red Planet”

1.8 Why Earth Is a Dynamic and Evolving Planet

1.9 The Rock Cycle

1.10 Organic Evolution and the History of Life

1.11 Geologic Time and Uniformitarianism

1.12 How Does the Study of Geology Benefit Us?

Key Concepts Review

**Learning Objectives**

*Upon completion of this material, the student should understand the following.*

* Geology is the study of Earth and also planets and moons in our solar system.
* Earth is a complex system of interconnected components that interact and affect one another in various ways.
* Theories are based on the scientific method and can be tested by observation or experiment.
* Geology plays an important role in human experience and affects us as individuals and societies.
* Global warming from human activities has already begun to impact the planet.
* The universe is thought to have originated approximately 14 billion years ago with a big bang. The solar system and planets evolved from a turbulent, rotating cloud of material surrounding the embryonic Sun.
* The solar system began in a solar nebula in which the Sun and planets, including Earth, formed.
* Earth consists of three concentric layers—core, mantle, and crust—and this orderly division formed during Earth’s early history.
* Plate tectonics is the unifying theory of geology and this theory revolutionized the science.
* The rock cycle illustrates the interrelationships between Earth’s internal and external processes and shows how and why the three major rock groups are related.
* The theory of organic evolution provides the conceptual framework for understanding the history of life.
* An appreciation of geologic time and the principle of uniformitarianism is central to understanding the evolution of Earth and its biota.
* Geology is an integral part of our lives.

**Chapter Summary**

* Earth can be viewed as a system of interconnected components that interact and affect one another. The principal subsystems of Earth are the atmosphere, hydrosphere, biosphere, lithosphere, mantle and core. Earth is a dynamic planet that continually changes because of the interactions among its various subsystems and cycles. Earth is a continually changing and dynamic planet because of the interactions among its various subsystems and cycles.
* Geology, the study of Earth, is divided into (1) physical geology, which is the study of Earth materials and the processes that operate both within Earth and on its surface; and (2) historical geology, which examines the origin and evolution of Earth, its continents, oceans, atmosphere, and life.
* The scientific method is an orderly, logical approach that involves gathering and analyzing facts about a particular phenomenon, formulating hypotheses to explain the phenomenon, testing the hypotheses, and finally proposing a theory. A theory is a testable explanation for some natural phenomenon that has a large body of supporting evidence.
* Geology is not only part of the human experience, examples of which can be found in art, music, and literature, but it also affects our daily lives as individuals, societies, and nation-states. A basic understanding of geology, and science in general, is critical for dealing with and finding solutions to the many environmental problems and issues facing humankind.
* The universe began, in what is popularly called the Big Bang, approximately 14 billion years ago. Astronomers have deduced this age by observing that celestial objects are moving away from each other in an ever-expanding universe. Furthermore, the universe has a pervasive background radiation of 2.7 K above absolute zero (2.7 K = –270.3°C), which is thought to be the faint afterglow of the Big Bang.
* About 4.6 billion years ago, our solar system formed from a rotating cloud of interstellar matter. As this cloud condensed, it eventually collapsed under the influence of gravity and flattened into a counterclockwise-rotating disk. Within this rotating disk, the Sun, planets, and moons formed from the turbulent eddies of nebular gases and solids.
* Earth formed from a swirling eddy of nebular material 4.6 billion years ago, accreting as a solid body and soon thereafter differentiating into a layered planet.
* Earth’s outermost layer is the crust, which is divided into continental and oceanic portions. The crust and underlying solid upper mantle, together known as the lithosphere, overlie the asthenosphere, a zone that behaves plastically and flows slowly. The asthenosphere is underlain by the solid lower mantle. Earth’s core consists of an outer liquid portion and an inner solid portion.
* The lithosphere is divided into a series of plates that diverge, converge, and slide sideways past one another.
* Plate tectonic theory provides a unifying explanation for many geologic features and events. The interaction between plates is responsible for volcanic eruptions, earthquakes, the formation of mountain ranges and ocean basins, and the recycling of rock materials.
* The three major rock groups are igneous, sedimentary, and metamorphic. Igneous rocks result from the crystallization of magma or the consolidation of volcanic ejecta. Sedimentary rocks are typically formed by the consolidation of rock fragments, precipitation of mineral matter from solution, or compaction of plant or animal remains. Metamorphic rocks result from the alteration of other rocks, usually beneath Earth’s surface, by heat, pressure, and chemically active fluids.
* The rock cycle illustrates the interactions between Earth’s internal and external processes and how the three rock groups are interrelated.
* The central thesis of the theory of organic evolution is that all living organisms evolved (descended with modifications) from organisms that existed in the past.
* Time sets geology apart from the other sciences except astronomy, and an appreciation of the immensity of geologic time is central to understanding Earth’s evolution. The geologic time scale is the calendar geologists use to date past events.
* The principle of uniformitarianism is basic to the interpretation of Earth history. This principle holds that the laws of nature have been constant through time and that the same processes operating today have operated in the past, although not necessarily at the same rates.
* Geology is an integral part of our lives. Our standard of living depends directly on our consumption of natural resources, most of which formed millions and billions of years ago.

**Enrichment Topics**

**Topic 1. Climate Change.** One of the major issues facing young people in their lives will be global warming. While climate has changed in Earth’s past, and has been warmer than even the most dire predictions for how temperatures will increase over the next few centuries, it is human systems that depend on climate being more-or-less constant and predictable. Some of the systems we depend on that could change include the following.

* The major agricultural areas could become too dry and hot to grow food. Moving agriculture closer to higher latitudes has political and environmental ramifications. For example, what if the American bread basket moves into Canada. What does that mean for the U.S.? Also, good soils must build up over decades and centuries. Just because the climate becomes favorable for agriculture in a more northern location does not mean that the soils will also be good. Many of the world’s people rely on subsistence agriculture, in which they grow enough food to meet their family’s needs and not much more. Harshening environmental conditions will damage the ability for many of these people to survive.
* Many people live in coastal areas, and much of society’s infrastructure is concentrated near coastlines. Sea level rise will cost millions of people their homes. In low-lying Florida, a one-foot rise in sea level, which could happen by the end of the century, will result in the loss of 100 feet of beaches. Communities are already having trouble protecting their homes and businesses, particularly during storms, and the situation will just get worse.
* Ecosystems are adapted to the climate conditions in which they evolved. Humans have restricted many of those ecosystems to certain areas, such as national parks. For example, the remaining redwood trees are found in national and state parks in California. If temperature and precipitation conditions become unfavorable, the redwoods in the park would die off but there is little undeveloped land for new forests to grow. Also, rising sea level will drown many coastal ecosystems, such as mangrove forests and coral reefs. These are important ecosystems for seafood sources and for coastal protection.

**Topic 2. Scale of the Solar System.** Use a football field analogy to convey to students the size of the solar system and relative proximities of the planets to the Sun.

Put the Sun on the goal line.

Mercury is on the 1 foot line

Venus is on the 2 foot line

Earth is on the 1 yard line

Mars is on the 1 1/2 yard line

Jupiter is on the 5 yard line

Saturn is on the 10 yard line

Uranus is on the 20 yard line

Neptune is on the 30 yard line

Pluto is on the 40 yard line.

On this same scale, the nearest star would be 500 miles away.

**Topic 3. Faith versus Science.** Science serves some of the same purposes that religion does. Science explains the way the world works, for example. But science is different from religion because science is based on things that are testable. You can do an experiment to see if something in science is correct. Still it is necessary to have faith in a few things in science. For example, we must have faith that the world is as we perceive it and that we are capable of understanding it. Science cannot address matters of faith. Since there is no scientific way to validate the supernatural, faith in the supernatural is not the same as a scientific theory or hypothesis

**Common Misconceptions**

**Misconception 1.** Geology is less scientific than physics or chemistry.

**Fact:** A science is distinguished by its methodology. Geology uses the scientific method in investigating questions about Earth (and other bodies in the universe such as the Moon and other planets). Although many geologic studies cannot be conducted under the tightly controlled conditions of a laboratory, but must be examined in the outside world, they are nonetheless approached in a strictly scientific way.

**Misconception 2:** A theory is “just” a theory. It is not highly regarded by all scientists.

**Fact:** A theory is as good as it gets in science. A law is a statement about something that happens all the time, every time; like the law of gravity explains what will happen if you release a coin held above the ground. A theory is an explanation of a complex set of phenomena. It is accepted by virtually all scientists and there is no major evidence that refutes it. The Theory of Evolution and the Theory of Plate Tectonics are both major frameworks on which most observations (field and experimental) in the biological and earth sciences rest. Neither science would make sense in the modern world without those theories.

**Lecture Suggestions**

1. Have the students look around the classroom for mineral substances (metal and plastic furniture, cement block or sheetrock walls, floors with vinyl tile or synthetic carpet, glass in light fixtures and windows). They should also keep in mind that mineral fuels are used for heating, lighting, and air-conditioning. Even natural fibers and materials in students' clothing (wool, cotton, silk, leather) depend on proper soil and the availability of fresh water.
2. Almost every day there are stories in the newspapers and on radio and television that are relevant to geology—about volcanic eruptions, earthquakes, floods, landslides, subsidence or collapse of old mines, water quality, pollution, waste (especially toxic) disposal. Start a file of these clips and introduce them at the appropriate places in the course. It can be very effective to display a printed article as you discuss that article. Or suggest that students bring in articles they come across or summaries of information from newscasts.
3. Ask the students if they can explain how a flipping a light switch makes light. We depend on science, yet the average person doesn't really understand how simple, long-existing technologies work. Discuss how many other things are common in everyday life but might be considered “magic.”
4. Point out ways in which people employ the scientific method in drawing conclusions in their daily lives. Extract from these examples the elements and sequence of thought embodied by the scientific method. What are the facts? What is the explanation? Contrast this method with conclusions based on the supernatural. Where does faith come in? Is faith important in science? If so, where?
5. Point out that broad conclusions that are arrived at via the scientific method and are relied upon in daily life are equivalents of a “scientific theory of (individual) human experience.” For example, one cannot safely stroll into the midst of moving traffic.
6. Demonstrate with an everyday example (e.g., a road-kill, the event being unseen, but its result later observed) that the scientific method can be used to construct hypotheses about events that have not been directly observed. Stress that the lack of opportunity to observe historical events in geology is more of an apparent, than a real, problem. There are many ways that scientists can use scientific method to infer past events: using radiometric dating to determine the age of a material, for example. Although particular historical events have only happened once, the class of events to which each belongs (e.g., mountain building) is represented by thousands of individual events, each of which can serve as either data or a test of a hypothesis or theory.
7. Clearly contrast the popular use of the term “theory” (meaning speculation, guess, or conjecture) with the legitimate scientific use of the term. Come up with some fun examples of how the word is misused in everyday language. For example, “My theory on why she dumped him is that he doesn’t drive a nice car.” Correctly speaking, that would be a hypothesis!
8. Teach students what a planet is by discussing why Pluto is no longer considered a planet. Encourage a class discussion on whether Pluto should regain its planetary status or remain as a lesser “dwarf planet.”
9. As Thomas Kuhn has proposed, plate tectonic theory represents perhaps the clearest example of how a reigning theory is questioned and is eventually discarded for another. In particular, emphasize the largely descriptive nature of geology and its hypotheses prior to plate tectonic theory as an analogy to the initial and latter stages of the scientific method. A discussion of plate tectonic theory could aid in illustrating the nature of the scientific method, the development of scientific theories, and the day-to-day business of doing science, as well as the elements and history of the theory itself. However, you may want to postpone this discussion until Chapter 2: Plate Tectonics: A Unifying Theory.
10. Emphasize the contrast in physical properties between the lithosphere and the asthenosphere and how these determine the behavior of plates.
11. The rock cycle is really the rock recycle: any rock can become any other type of rock. The rock cycle is a description of the processes by which rocks and materials (such as magma or sediments) are endlessly transformed from one state to another.
12. When covering the principle of uniformitarianism, ask a number of students to each give one example of this principle drawn from their daily experience.
13. Illustrate the importance of natural resources to societies with an example of a war that was fought over natural resources or a society that failed due to a shortage of natural resources. Examples might include the Persian Gulf War, African wars fought for diamonds, and the failure of the society on Easter Island due to loss of resources.

**Consider This**

1. Why is plate tectonics a theory and not a fact?
2. Why is plate tectonics called the unifying theory of geology? How could the distribution of volcanoes, earthquakes, mountain ranges, and mineral deposits be explained without it?
3. Why can the rock cycle be considered a part of plate tectonics? Does the fact that the rock cycle involves the hydrologic cycle and atmospheric processes separate it from plate tectonics? How are hydrologic and atmospheric processes also a part of plate tectonics?
4. How would understanding earth history be different without the principle of uniformitarianism?
5. Students are very likely to have had little or no exposure to the theory of organic evolution. Explaining the theory carefully and with lots of evidence to back it up is extremely important for the understanding of science by these citizens, future parents, school board members, and book buyers.
6. What properties make Earth habitable while the other planets in our solar system are not?

**Important Terms**

principle of uniformitarianism

geologic time scale

fossils

organic evolution

metamorphic rocks

sedimentary rocks

igneous rocks

rock cycle

minerals

rock

plate tectonic theory

crust

plates

lithosphere

asthenosphere

mantle

core

Jovian planets

terrestrial planets

solar nebula theory

Big Bang

hypotheses

scientific method

theory

geology

system

**Internet Sites, Videos, Software, and Demonstration Aids**

**Internet Sites**

1. Geology.com <http://geology.com/>

Geology articles and news including information about careers in geology, a highly paid profession.

1. The Grand Canyon Suite by Ferde Grofe is a good example of geology-inspired art. You can listen to it here: <http://www.emusic.com/album/Erich-Kunzel-Grofe-Grand-Canyon-Suite-Gershwin-Catfish-Row-MP3-Download/11156792.html>
2. Introduction to the ~~Nine~~8 Planets <http://nineplanets.org/>

This longstanding website presents information on the objects of our solar system, focusing on scientific knowledge, but also the history and mythology.

1. Earth Observatory <http://earthobservatory.nasa.gov/>

This site is the portal to satellite images of Earth from space and focuses on natural processes and also the visible changes due to those processes or human influences.

1. Smithsonian: This Dynamic Earth <http://www.mnh.si.edu/earth/>

Introductory geology presented in a multimedia format.

1. Real Climate <http://www.realclimate.org>

Real news about climate change by real climate scientists.

1. Intergovernmental Panel on Climate Change <http://ipcc.ch/>

Every few years the IPCC issues a report that is the work of many scientists who work on the issue of climate change. This report is highly regarded by scientists, politicians, and journalists.

1. Pew Center on Climate Change <http://www.pewclimate.org>

Climate change news and politics at the state, federal and international levels.

**Videos**

1. Earth: The Biography, BBC, DVD (2008, 230 mins.)

Satellite images and computer graphics show some of Earth’s most remarkable features.

1. Nature of Earth: An Introduction to Geology. The Teaching Company, DVD (2006, series of 36 thirty-minute lectures)

The drama of geology is all around you.

1. Planet Earth – The Complete BBC Series. Discovery, DVD (2007, 550 mins.)

An 11-part series of different environments and the living creatures and inhabit them, narrated by David Attenborough.

1. The Geology of the United States. Insight Media, DVD (1995, 20 mins.)

The principle landforms and physiographic provinces of the U.S.

1. The Universe, Collectors Set, HISTORY, DVD(2009; 33 hours, 41 mins.)

Computer graphics and animation, NASA images and scientific information meld together in this exploration of the universe.

1. Geography Resources: Introducing Mapping Concepts. Insight Media, DVD (2004, 25 mins.)

Principles of maps and mapping including the use of the Global Positioning System.

1. Geologic Maps: Portraits of the Earth. Insight Media, DVD (2005, 20 mins.)

An introduction to what geologic maps depict.

1. Journey to the Edge of the Universe, National Geographic, DVD (2009, 91 mins.)

Travel through the universe in a single unbroken image by the Hubble Space Telescope.

1. The Planets, New Video Group DVD (1999, 400 mins.)

A guided journey through the solar system using NASA footage.

1. Wonders of the Solar System, BBC Warner, DVD (2010, 300 minutes)

Some of the most amazing features of our solar system using the latest scientific knowledge and images.

1. An Inconvenient Truth DVD (2006, 96 mins.)

Vice President Al Gore’s Academy Award winning 2006 documentary of global warming and its potential effects on our planet.

1. Warnings from the Ice, NOVA PBS DVD (2008, 56 mins.)

Antarctic ice sheets yield evidence of how the planet is warming.

1. Global Warming: The Rising Storm, Ambrose Video Pub., Inc. DVD (2007, 114 mins.)

The effects of global warming on the planet that are already being seen.

1. Global Warming: Science and Solutions, Ambrose Video Pub., Inc. DVD (2006, 116 mins.)

Possible solutions to the planet’s rising temperatures.

1. Miracle Planet, Ambrose Video Pub., Inc. DVD (2006, 248 mins.)

Earth’s amazing evolution over more than 4 billion years.

1. Earth Revealed. Annenberg Media http://www.learner.org/resources/series78.html (1992, 30 mins., free video):

* #1: Down to Earth. Annenberg/CPB Collection

Comparisons of Earth with Venus and Mars.

**Answers to Figure-Related Critical Thinking Questions**

❯❯ Critical Thinking Question Figure 1.3

*Every year the life expectancy of the average American increases as well as our usage of minerals, metals, and fuels needed over a lifetime to maintain our standard of living. Is this increase sustainable, and is there anything that can be done to balance the depletion of natural resources but still maintain a high standard of living? How does our increasing consumption of these natural resources impact the rest of the world’s population?*

Although population growth in undeveloped countries threatens sustainability of natural ecosystems and resource use, over-consumption in developed countries may pose a more serious problem. At least part of the rise in global consumption is the result of population growth. The U.N. projects that world population will increase 41 percent by 2050, to 8.9 billion people, with nearly all of this growth in developing countries.  
  
This surge in human numbers threatens to offset any savings in resource use from improved efficiency, as well as any gains in reducing per-capita consumption. Even if the average American eats 20 percent less meat in 2050 than in 2000, total U.S. meat consumption will be 5 million tons greater in 2050 due to population growth.

The United States, with less than 5 % of the global population, uses about a quarter of the world’s fossil fuel resources—burning up nearly 25 % of the coal, 26 % of the oil, and 27 % of the world’s natural gas. As of 2003, the U.S. had more private cars than licensed drivers, and gas-guzzling sport utility vehicles were among the best-selling vehicles. New houses in the U.S. were 38 % bigger in 2002 than in 1975, despite having fewer people per household on average.

❯❯ Critical Thinking Question Figure

*What types of geologic events would cause interruptions to the idealized cycle shown on the margin of the rock cycle? What do you think is more common and why—completion of an idealized cycle, or one in which there are interruptions?*

Interactions between plates through plate tectonics can interrupt the circular ideal of the rock cycle. In a sense, the interruptions are the norm rather than the ideal.

**Suggested Answer to Selected Short Answer Question**

(*Answers to question 6 and question 9 provided in the appendix to the text*)

7. How does the solar nebula theory account for the formation of our solar system, its features, and evolutionary history?

**Suggested Answer:** According to The Solar Nebula Theory, stars form in massive, dense clouds of molecular hydrogen called giant molecular clouds. These clouds are gravitationally unstable, and matter coalesces into smaller, denser clumps inside. These clouds collapse and form stars. This can give birth to planets. So, the formation of planetary systems is thought to be a natural result of star formation. The process is thought to take at least 100 million years.