**Instructor’s Manual to accompany**

***Physical Geology, 16/e* by Plummer/McGeary/Carlson/Hammersley**

**CHAPTER 1 – INTRODUCING GEOLOGY, THE ESSENTIALS OF PLATE TECTONICS, AND OTHER IMPORTANT CONCEPTS**

 **Overview**

Geology uses the scientific method to explain natural aspects of the Earth - for example, how mountains form or why oil resources are concentrated in some rocks and not in others. This chapter briefly explains how and why Earth's surfaces, and its interior, are constantly changing. It relates this constant change to the major geological topics of interaction of the atmosphere, water and rock, the modern theory of plate tectonics, and geologic time. These concepts form a framework for the rest of the book. Understanding the "big picture" presented here will aid you in comprehending the chapters that follow.

**Learning Objectives**

1. Geology is the scientific study of the Earth. Physical geology is that division of geology concerned with Earth materials, changes in the surface and interior of the Earth, and the dynamic forces that cause those changes.

2. Geology is important because it a) supplies us with things we need, b) understanding how the Earth operates allows us to better protect and preserve the environment, c) allows us to avoid geologic hazards like earthquakes, tsunamis, volcanic eruptions and floods, and d) understanding our surroundings.

3. To understand geology we must understand how the solid Earth interacts with water, air and living organisms. We must also comprehend the effects of releasing huge amounts of the Earth’s energy. It is useful to think of the Earth as being part of a system. The Earth system is composed of the atmosphere, hydrosphere, biosphere and geosphere. All four subsystems continuously interact to shape the planet and its surface.

4. The Earth can be viewed as a giant machine driven by two heat engines, an internal engine that releases heat from the hot interior of the Earth thru volcanoes and moving plates, and an external heat engine driven by solar energy that evaporates sea water creating rain and snow, producing glaciers and eroding away rocks, carving mountains as it drains away thru streams and transporting loose sediment to form new rock materials.

5. The Earth's interior has been subdivided into three concentric zones based on chemical composition: crust (continental crust; the solid ocean floor is sometimes called oceanic crust), mantle (thickest zone), and core (predominantly iron).

6. Another way that the Earth’s interior is subdivided is based on its geophysical properties, primarily, whether the layers are solid, liquid, or somewhere in between. The lithosphere is the solid crust and upper mantle that is broken into pieces, called tectonic plates. Tectonic forces caused by the motion of tectonic plates result in vertical and horizontal deformation of the earth’s interior. Beneath the lithosphere is the soft, partially solid "lubricating" layer called the asthenosphere upon which the plates move. Below the asthenosphere is more solid mantle and finally the core. The core is composed of the liquid outer core and the solid inner core.

7. Plate tectonics is a theory that views the Earth's lithosphere as broken into plates that are in motion over partially molten asthenosphere. At mid-oceanic-ridges, tectonic plates are diverging as magma rises from the asthenosphere, pushes the ridge crests apart, and solidifies in the fissures created. Ridges spread at a rate of 1-18 centimeters per year and are responsible for the opening of ocean basins. Transform boundaries occur where plates slide past each other, such as the San Andreas fault. Converging boundaries reflect either subduction, where oceanic plates descend into the mantle, or collision, where two continents collide.

8. Rocks are formed as a result of tectonic activity. When molten rock, magma, at the high internal temperatures found inside the Earth are pushed closer to the surface by tectonic forces, they will begin to crystallize out of the magma and form **igneous rocks**. **Metamorphic rocks** may be formed from high-temperature and pressure at subduction zones, if melting does not occur. Additionally, rocks that initially formed at depth under high temperatures and pressures become unstable as they are pushed toward the surface. Surface processes cause these rocks to break down into pieces, called sediment. The sediment is, typically, transported by streams and will eventually be deposited and become **sedimentary rock** as compaction occurs and/or cement forms in the empty spaces between the sedimentary grains.

9. The scientific method provides an objective way to analyze how the earth behaves and is useful for the scientific study of geological phenomena. It involves a process, beginning with an inquiring mind asking a difficult question, followed by the collection of data related to the question. Collection of the data also involves observations and much thought, eventually resulting in an idea or hypotheses of how things work and an associated set of predictions that would result if the hypotheses were true. When the predictions are tested, they will either support the hypotheses and lead to its acceptance as a theory or raise more questions resulting in the idea being discarded or rethought (see Box 1.4). Continental drift is an example of a hypothesis. Plate tectonics is an example of a theory.

10. Geology involves enormous amounts of time, vastly greater than human lifetimes. The Earth is about 4.6 billion years old. Most geological processes are slow and take place over many millions of years. Fast, to a geologist, is an event or process completed in a million years or less. Complex life forms have existed on the Earth for at least the past 545 million years. Humans have only been on Earth for about 3 million years; modern humans (homo sapiens) evolved in Africa about 200,000 years ago.

**Short Discussion/Essay**

1. What are four good reasons to know about geology?
2. What are geological resources?
3. How can the need for resources be balanced with concerns for the environment?
4. What are some possible careers one could pursue as a geologist?

5. What are the four Earth systems and what are some ways they interact?

6. How do volcanoes and ocean trenches form?

7. What factors influence whether two converging plates will form a subduction zone or a collisional mountain belt?

8. Explain how isostatic adjustment influences landforms.

9. How do sedimentary rocks form?
10. Contrast rapid geologic events with slow geologic events using the concept of geologic time.

**Longer Discussion/Essay**

1. Explain the concept of external and internal heat engines driving Earth processes.
2. Describe the theory of plate tectonics, how it works and how it can be used to explain where earthquakes and volcanic eruptions occur.
3. Describe the scientific method and how it is used by geologists.
4. How did plate tectonics move from hypothesis to theory?
5. Why is the lithosphere constantly changing through geologic time?

6. What challenges face geologists interested in mitigating the effects of geologic hazards like tsunamis and volcanic eruptions?

7. What are the positive and negative aspects of producing oil in Prudhoe Bay?

**Selected Readings**

Most of the material in this chapter is covered in detail in later chapters; appropriate references are given in the summaries of those chapters. The references listed below are appropriate to this chapter specifically.

Durbin, J.M., 2002, The benefits of combining computer technology and traditional teaching methods in large enrollment geoscience classes, Journal of Geoscience Education (50): 56-63.

Gregor, C.B., R.M. Garrels, F.T. Mackenzie and J.B. Maynard, eds., 1988. *Chemical cycles in the evolution of the Earth*. Somerset, NJ: John Wiley and Sons.

Harris, S.L. 1990. *Agents of chaos: earthquakes, volcanoes, and other natural disasters*. Missoula, MT: Mountain Press Publishing Company.

Kobluk, D.R. 1993. "*Enhancing contact with students in high enrollment Geology courses with electronic bulletin boards*," Journal of Geological Education 41 (1): 32-34.

McPhee, J. 1981. *Basin and Range*. New York: Farrar, Straus and Giroux. McPhee presents a vivid (and accurate) picture of how a geologist works and portrays some of the most interesting geologic characteristics of the United States. Other McPhee books are listed at the end of chapters 9 and 20 of the textbook.

Rhodes, F.H.T. and R.O., Stone, eds., 1981. *Language of the Earth*. New York: Pergamon Press (paperback). An anthology of writings bearing on geology. Some of the chapter headings are: "Geology and Poetry;" "Humor in Geology;" "Geology and the Arts;" "Geopolitics." Authors include Mark Twain, Herbert Hoover, Ernest Hemingway and Charles Darwin.

Schrum, S. A., 1991. *To Interpret the Earth: Ten Ways To Be Wrong*. New York: Cambridge University Press.

Sullivan, M. A., and Y. Dilek, 1997. "*Enhancing Scientific Literacy Through the Use of Information Technology in Introductory Geoscience Classes*," Journal of Geological Education 45 (4): 308-313.