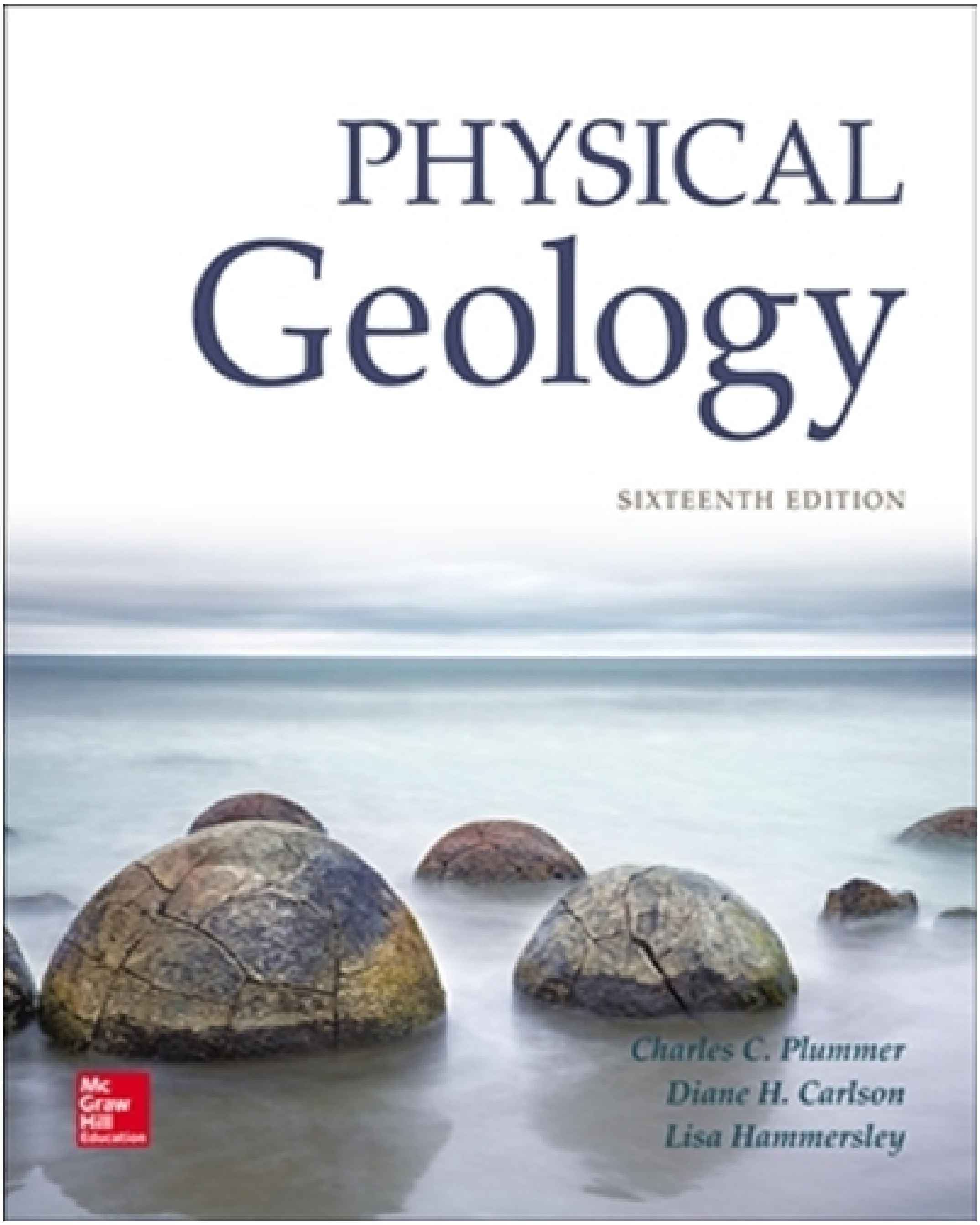
Solutions for Physical Geology 16th Edition by Plummer



Solutions

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.

CHAPTER 2 - ATOMS, ELEMENTS, AND MINERALS

Overview

This chapter is the first of six related to Earth materials. The following chapters are mostly about rocks. Nearly all rocks are made of minerals. Therefore, to be ready to learn about rocks, you must first understand what minerals are as well as the characteristics of some of the most common minerals.

In this chapter, students are introduced to some basic principles of chemistry. This is intended as a refresher for students familiar with chemistry and an introduction for students who have not encountered this material in previous schooling. This will help students understand material covered in the chapters on rocks, weathering, and the composition of Earth's crust and its interior.

Every mineral is composed of specific chemical elements, the atoms of which are in a remarkably orderly arrangement. A mineral's chemistry and the architecture of its internal structure determine the physical properties used to distinguish it from other minerals. This chapter covers material important for readily determining physical properties and use them to identify common minerals. (Appendix A of the text is a further guide to identifying minerals).

Learning Objectives

1. Minerals are naturally-occurring, inorganic (not made from organic material), crystalline (orderly three-dimensional-arrangement of atoms) solids with a specific chemical composition. Chemical formulas can tell you which elements are in a mineral in and in what proportions.

2. Rocks are naturally formed aggregates of minerals or mineral-like substances. Most rocks are composed of grains or crystals of one or more minerals. A few rocks, like coal and obsidian, are exception to the rule that rocks are made from minerals. Coal is made from organic material, and obsidian is made from noncrystalline volcanic glass

3. Most rocks are composed of minerals. Minerals are composed of elements. Elements are substances that cannot be broken down by ordinary chemical methods. Atoms are the smallest particles of elements. They are constructed of protons, neutrons (forming the nucleus) and electrons. Atomic mass number, atomic number and atomic weight control the “character" of an element, particularly its isotopes. Electrons spin around the nucleus, spending most of their time at an energy level. Energy levels are filled from the inner, lowest energy level to the outer level. The most stable configuration of an atom is to have the outermost level full of electrons.

4. Most elements do not have a stable, full outer energy level in their atoms and exist as ions. These elements will typically bond with other elements to attain a stable

configuration. Chemical activity is related to ions and their bonding. Atoms can obtain a full outer energy level by either exchanging electrons (ionic bonding) or sharing electrons (covalent and metallic bonding). Ionic bonding is the most common. Some minerals exhibit more than one type of bond. Covalently bonded sheet silicates have weak electrostatic bonds between the sheets, allowing the sheet silicates to have a pronounced one directional cleavage. Micas and graphite exhibit this characteristic.

5. Ions may be positive (cations) or negative (anions). Like charges repel each other and opposite charges attract one another to form bonds. This characteristic results in ions of different sizes being packed together to form a repeating crystalline structure. Specific chemical composition in minerals reflects the orderly internal arrangement of atoms. Of particular importance are the crystal structures that result from the two most common elements in the Earth's crust, silicon and oxygen, which together are termed silica. Oxygen accounts for half the weight of the crust. Silicon is the second most abundant element in the crust and the silicate minerals are the most common minerals in the crust.

6. Crystalline substances have a three-dimensional, regularly repeating, and orderly pattern of their constituent ions. The silica tetrahedron is the basic "building block" of the silicate minerals. The silica tetrahedron consists of one atom of silicon and four atoms of oxygen. Silicate structure reflects the arrangement of silica tetrahedra and the number of shared oxygen atoms between tetrahedra. These structures include: isolated silicate structure (no shared oxygens), chain-silicates (two shared oxygens), sheet silicates (three shared oxygens), and framework silicates (four shared oxygens).

7. A small number of rock-forming minerals comprise most of the crust. Five silicate mineral groups (feldspar, quartz, pyroxene, amphibole, and mica) account for greater than 90% of the Earth's crust. Feldspars are the most common crustal mineral, while olivine is the most abundant mineral in the Earth as a whole. Nonsilicates include carbonates, sulfates, sulfides and oxides that are classified by their negative ion, as well as native elements that are composed of a single element. Native elements include ore minerals of commercial value such as gold, silver and diamonds.

8. Some minerals show variation in their composition or structure. Olivine $(MgFe)_2SiO_4$ is a mineral that allows iron (Fe) and magnesium (Mg) to substitute for one another in the crystalline structure. Both ions have the same charge (+2) and are close in size. Olivine forms a **solid solution series** ranging in composition from Fe_2SiO_4 to Mg_2SiO_4 and all proportions in between. Some minerals show compositional zoning with one cation dominating in the center of the crystal and another on the outer rim. There are also some minerals, called **polymorphs** that have exactly the same chemical composition but different crystalline structures. Calcite/aragonite and diamond/graphite are two pairs of minerals that are polymorphs. In many cases polymorphs form under different pressure conditions which alters the bonding and, thus, the crystalline structure.

9. Physical properties are used to identify minerals. These include color, streak, luster, hardness, external crystal form, cleavage, fracture, specific gravity, special properties

(smell, taste, striations, magnetism), and other properties (double refraction, effects of polarized light, x-ray defraction). Chemical tests can also be used to identify minerals.

10. Minerals form under a wide variety of conditions. Some form on the Earth's surface, others deep inside the Earth. Some even form in the atmosphere. Silicate minerals primarily crystallize out of molten rock called magma. Carbonates precipitate out of cave and spring waters or, evaporites, like salt, precipitate out of the ocean or lakes that are evaporating.

Short Discussion/Essay

1. Explain the general public's confusion with the term mineral.
2. How might it be argued that ice is actually a mineral?
3. What does the chemical formula tell you about a mineral?
4. Why are gold and diamonds valuable?
5. How can graphite and carbon have the same composition?
6. Is plastic a mineral? Why or why not?

Longer Discussion/Essay

1. Why are oxygen and silicon the most common elements in the Earth's crust?
2. Why are silicates the most common minerals in the Earth's crust?
3. If all minerals are crystalline, why don't they always form crystals?
4. How does silicate structure control the physical properties of silicate minerals, particularly cleavage?
5. Why is limestone a rock, not a mineral, even though it has the same chemical composition as calcite?
6. How do ions bond together to form crystalline structures?
7. What mineral properties are affected by the strength of the bond between the atoms and elements?

Selected Readings

Mineralogy is a basic subdiscipline of geology and there are many textbooks that deal with this subject. Some articles of interest:

Kirshner, R. P. 1994. "*The Earth's elements*," Scientific American 271:58-65.

Mueche, G.K. and Moller, P. 1988. "*The not-so-rare earths*," Scientific American 258:72-77

Check out this website for more examples of mineral properties and for practice tests:

http://facweb.bhc.edu/academics/science/harwoodr/Geol101/index.htm

This website offers practice mineral identification tests (located under the Lab Materials tab) that require the student to fill out physical properties of each mineral identified

Plummer 16e Answers to EOC

Chapter 1

10.A, 11.G, 12.D, 13.C, 14.D, 15.D, 16.C, 17.D, 18.C, 19.A 20.C

Chapter 2

11.B, 12.A, 13.C, 14.C, 15.B, 16.A, 17.D, 18.C, 19.C, 20.A, 21.D, 22.C, 23.C