Chapter 3
Minerals: The Building Blocks of Rocks

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Chapter Outline

Introduction
LO1 Matter: What Is It?
LO2 Explore the World of Minerals
LO3 Mineral Groups Recognized by Geologists
LO4 Physical Properties of Minerals
LO5 Rock-Forming Minerals
LO6 How Do Minerals Form?
LO7 Natural Resources and Reserves

Learning Outcomes

After reading this unit, the students should be able to do the following:

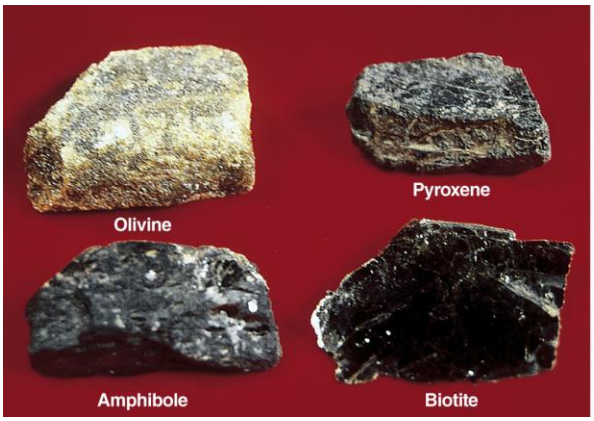
LO1 Define matter
LO2 Explore the world of minerals
LO3 Identify mineral groups recognized by geologists
LO4 Identify physical properties of minerals
LO5 Recognize rock-forming minerals
LO6 Explain how minerals form
LO7 Recognize natural resources and reserves

Chapter Summary

- Matter is composed of chemical elements, each of which consists of atoms. Protons and neutrons are present in an atom's nucleus, and electrons orbit around the nucleus in electron shells.

- The number of protons in an atom's nucleus determines its atomic number. The atomic mass number is the number of protons plus neutrons in the nucleus.

- Bonding results when atoms join with other atoms; different elements bond to form a compound. With few exceptions, minerals are compounds.
- Ionic and covalent bonds are most common in minerals, but metallic and van der Waals bonds are found in some.
- Minerals are crystalline solids; they possess an ordered internal arrangement of atoms.
- Mineral composition is indicated by a chemical formula, such as SiO_2 for quartz.
- Some minerals have a range of compositions because different elements substitute for one another if their atoms are the same size and have the same electrical charge.
- More than 3,500 minerals are known, and most of them are silicates. The two types of silicates are ferromagnesian (iron or magnesium-containing) and nonferromagnesian.



- In addition to silicates, geologists recognize carbonates, native elements, hydroxides, oxides, phosphates, halides, sulfates, and sulfides.
- Structure and composition control the physical properties of minerals, such as luster, crystal form, hardness, color, cleavage, fracture, and specific gravity.
- Several processes account for the origin of minerals, including cooling magma, weathering, evaporation of seawater, metamorphism, and organisms using dissolved substances in seawater to build their shells.
- A few minerals, designated rock-forming minerals, are common enough in rocks to be essential to their identification and classification. Most rock-forming minerals are silicates, but some carbonates are also common.

- Many resources are concentrations of minerals or rocks of economic importance. They are further characterized as metallic resources, nonmetallic resources, and energy resources.

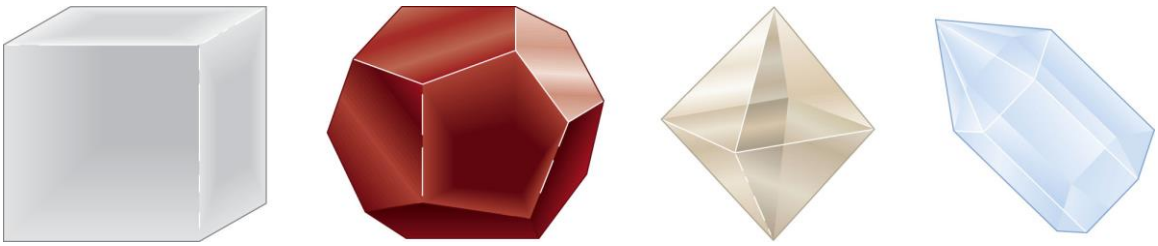
- Reserves are that part of the resource base that can be extracted profitably. Distinguishing a resource from a reserve depends on market price, labor costs, geographic location, and developments in science and technology.

- The United States must import many resources to maintain its industrial capacity. Canada is more self-reliant, but it too must import some commodities.

Lecture Suggestions

1. Cleavage planes are probably the most difficult mineral property for students to recognize. Point out that they can be recognized by naturally fractured and flat surfaces, which all reflect or "wink" light at the same time when turned in the light. Also point out that although surfaces that are parallel to one another have the same cleavage plane, a sample need not show evidence of more than one cleavage surface in order to qualify it as a cleavage plane.

2. To demonstrate that cleavage within a crystal continues down to a very small scale (theoretically, all the way to an atomic scale), examine a piece of mica or a crystal of halite and point out that the fracture lines that can be seen indicate the presence of additional planes of weakness within the crystal. Furthermore, one could hammer a halite crystal until the fragments are microscopic, and the three cleavage planes would still give each fragment a cubic shape.



3. Use a broken sample of crystalline quartz to illustrate the difference between crystal faces and cleavage planes. The quartz crystal faces are flat, but when broken, the crystal fractures like glass; it does not possess a cleavage. Compare this to a halite or calcite crystal, both of which do break along flat cleavage planes. Point out that crystal faces are naturally flat, reflective surfaces but differ from cleavage planes in that the former result from a crystal having grown into an open space, while the latter, which is a result of inter-atomic bonding, is seen after fracturing.

4. While the students are examining the quartz crystals, point out the fine, parallel striations that are on the crystal faces. These striations, which are perpendicular to the long axis of the original crystal, are always present on natural quartz crystals, and develop during growth. Note that many "quartz crystals" sold as jewelry, art objects, or trinkets do not exhibit these striations. These commercially available crystals, evidently, have either been ground and polished, removing the lines and possibly reshaping the faces, or they might not be real quartz at all. If these "crystals" are actually glass, how could the student tell?

5. Note that streak is a more constant property for a mineral than the overall color, which can vary. Compare the streaks of different forms of the mineral hematite (Fe_2O_3). If you can, obtain samples that are earthy, sub-metallic, and metallic (specular hematite or specularite). They should all exhibit the same "dried blood" red streak, though their overall colors, as well as lusters, are different. The name hematite, incidentally, is from the Greek *haema,* meaning blood (the same root found in hemoglobin, hemophiliac, and hematology), which is in allusion to the color of the streak.

Enrichment Topics

Topic 1. Theory of the Atom. Although the theory of matter as a composite of extremely small independent particulate units known as atoms originated with Greek philosophers, it is only recently that scientists have been able to observe, photograph, and even manipulate single atoms and their movement, using the scanning electron microscope. Thus, until the invention of the electron microscope, the theory of the atom and all theory based on it were deduced from observation and experiment, the subject never having been observed. This is an example of how evidence can be used to create hypotheses and theories.

Topic 2. Chemical Composition of the "Average" Rock. It is interesting to look at the volume percentages of the components of the Earth's crust. The volume percentages of the eight most common elements are:

Oxygen = 93.8%
Silicon = 0.9%
Potassium = 1.8%
Aluminum = 0.5%
Sodium = 1.3%
Iron = 0.4%
Calcium = 1.0%
Magnesium = 0.3%

Note that these percentages add up to 100.0%. This means that all other elements combined, including some very economically important ones, are present in just miniscule traces.

Topic 3. A Gold Rush in Greek Mythology. Strabo, an ancient Greek historian and geographer, wrote that the inhabitants of Colchis, a country on the eastern shore of the Black Sea, used to separate gold carried down from the mountains in streams. They did this by running the stream sediments, in water, through troughs lined with fleeces. The gold stuck to the fleeces, while the accompanying sediment was carried away. These fleeces were then hung to dry, after which the gold could be knocked off, like beating a carpet. According to Greek mythology, tales of the "Golden Fleece" inspired Jason and his crew on the Argo, and these Argonauts (the Greek *nautikos* means sailor) sailed in search of it.

Topic 4. Mega Crystals. In "the Sistine Chapel of Crystals," gypsum crystals up to 50 feet long are found. They are the largest natural crystals on Earth! How did these crystals form? Unlike most caves, these caves are hot! Why are they hot? There is a plan to open the cave for tourists. How can this be done without destroying this beautiful natural resource? http://www.crystalinks.com/mexicocrystals.html

Topic 5. Hot Topics in Mineralogy. Elements Magazine contains articles on current research in mineralogy, geochemistry, and petrology. You can access complete articles online if your institution subscribes to the magazine: http://www.elementsmagazine.org/index.htm

Common Misconceptions

Misconception 1: Geologists are all rock hounds.
Fact: While all practicing geologists need to know something about rocks and minerals, only a relatively small proportion actually collects, seeks, or studies rocks for a profession. Many geologists are employed by the fossil fuel industry, searching for deposits of petroleum, natural gas, and coal. Many others are engaged in the environmental and hydrologic fields, helping discover, define, and remedy problems such as pollution, water supply, and waste disposal. Still others apply their skills to engineering geology problems, helping locate sites for dams, bridges, and other structures. Some participate in fields of study in which rocks and minerals play little part.

Misconception 2: If a stone scratches glass, it must be a diamond.
Fact: Since glass has a hardness (measured on the Mohs scale) of about 5½, then any mineral with a greater hardness can scratch it. This includes most of the rock-forming silicates.

Consider This

1. Can a rock be composed of only one mineral? Why or why not? If so, give an example.

2. Can a native element be a mineral? Can a native element be a rock? Why or why not? If yes, give examples of each case.

3. Why don't some minerals, such as quartz, break along cleavage planes, while other minerals, such as halite, always do?

4. What properties of a mineral might give it special powers, such as the ability to heal? Since there are none, what is the reason that so many people think that minerals do possess powers? This is a good time to talk about the difference between science and other types of knowledge.

5. Why are physical properties more important than chemical composition in determining whether or not a mineral is valued as a gemstone?

6. List at least 20 common items that have been derived or fabricated from mineral resources.

7. Give some examples of how searching for and controlling (or trying to control) mineral resources have played a major role in human history.

Key Terms

atom
atomic mass number
atomic number
bonding
carbonate mineral
cleavage
compound
covalent bond
crystal
crystalline solid
density
electron
electron shell
element
ferromagnesian silicate
hardness
ion
ionic bond
luster
mineral
neutron
nonferromagnesian silicate
nucleus
proton
reserve
resource
rock
rock-forming mineral
silica
silica tetrahedron
silicate
specific gravity

Internet Sites, Videos, Software, and Demonstration Aids

Internet Sites

1. Diamond Factory. NOVA scienceNOW, PBS (2009, 14:35):
   http://www.pbs.org/wgbh/nova/sciencenow/0401/01.html
   Synthetic diamonds and how they can now be created to rival the real thing.

2. The Mineral and Gemstone Kingdom: http://www.minerals.net/
   A complete guide to rocks, minerals, and gemstones.

3. Mineral Galleries: http://mineral.galleries.com/
   Interesting features of minerals by name, class, and properties. Also includes information on rocks "The Home of Minerals."

4. Smithsonian Gem & Mineral Collection: http://www.gimizu.de/sgmcol/
   Some of the spectacular mineral and gem samples housed at the Smithsonian National Museum of Natural History.

5. Ask-A-Geologist: http://walrus.wr.usgs.gov/ask-a-geologist/
   Get answers to any Earth Science questions from the United States Geological Survey.

6. Mindat.org: http://www.mindat.org/index.php
   A mineral and locality database in which you can search for minerals by properties, chemistry, name, and association.

Videos

1. *Secrets in Salt.* NOVA scienceNOW, PBS, free video (2009, 11:50)
   http://www.pbs.org/wgbh/nova/sciencenow/0405/02.html
   Traces of early life are found in 250 million year old salt deposits.

2. *Elements of Earth Science: Rocks, Minerals and Soils.* Insight Media (2005, 30 min.)
   The rock cycle, minerals, soil, and fossil fuels are discussed in this DVD.

3. *Introduction to Rocks and Minerals.* Insight Media (2004, 25 min.)
   The characteristics of common minerals and rocks, and how they are identified.

4. *Core Geology.* Ambrose Video (2007, 30 min.)
   Natural resources and their importance to civilizations throughout human history.

5. *Diamonds.* Nature, PBS (56 min.)
   Discover the processes that create diamonds and the uses of these beautiful minerals to humankind.

6. *Earth Revealed.* Annenberg Media: http://www.learner.org/resources/series78.html (1992, 30 min., free video):
   - #12: Minerals: The Materials of Earth. A primer on minerals, how they are studied, and their importance to human civilization.

7. *Planet Earth.* Annenberg Media: http://www.learner.org/resources/series49.html (1986, 1 hour, free video)
   - #5: Gifts from the Earth. Earth's Natural Resources. Plate tectonics and how it has revolutionized the way geologists search for natural resources.

Software

1. *Rocks! & Minerals.* ScienceWorks, Camcor, Inc.
   Includes 53 minerals and 27 common rocks for lab simulation.

Slides and Demonstration Aids

1. *Earth Resources.* Insight Media, CD-ROM (2008)
   Images of 74 features of natural resources, including ore deposits and how they are obtained.

2. *Key to Minerals.* Insight Media, CD-ROM (1999)
   How to identify minerals, using practical identification techniques in an interactive format.

3. *Minerals.* Insight Media, CD-ROM (2005)
   High-quality, high-resolution images of minerals, especially rock forming and metallic and non-metallic specimens.

4. *Mineral Identification.* Insight Media, CD-ROM (2005)
   High-resolution images that show the ways to identify minerals.

5. Science Stuff, http://www.sciencestuff.com/, has an assortment of rock and mineral collections, including:

- Introductory Earth Science Rocks and Minerals.
- Natural Crystal Collection.
- Gem Minerals.
- Scale of Hardness Collection.
- Advanced Rock and Minerals Collection.