Essentials of Geology, 11e

Matters and Minerals

Chapter 2

Instructor – Jennifer Barson
Spokane Falls Community College
Geology 101

Stanley Hatfield
Southwestern Illinois College

Jennifer Cole
Northeastern University

Minerals

Building blocks of rocks

- Definition of a **mineral**
  - Naturally occurring
  - Inorganic solid
  - Ordered internal molecular structure
  - Definite chemical composition
- Definition of a **rock**
  - A solid aggregate or mass of minerals

Composition of Minerals

- **Elements**
  - Basic building blocks of minerals
  - Over 100 known (92 naturally occurring)
- **Atoms**
  - Smallest particles of matter
  - Retain all the characteristics of an element

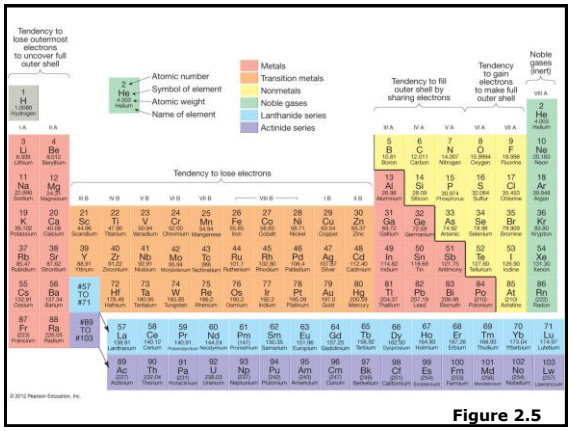


Figure 2.5

Composition of Minerals

- **Atomic structure**
  - Central region called the **nucleus**
    - Consists of **protons** (positive charges) and **neutrons** (neutral charges)
  - **Electrons**
    - Negatively charged particles that surround the nucleus
    - Located in discrete energy levels called **shells**

Idealized Structure of an Atom

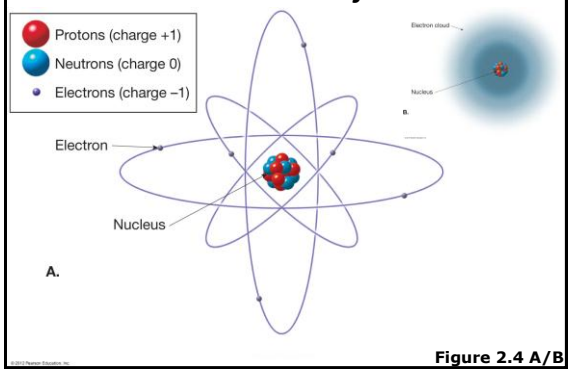
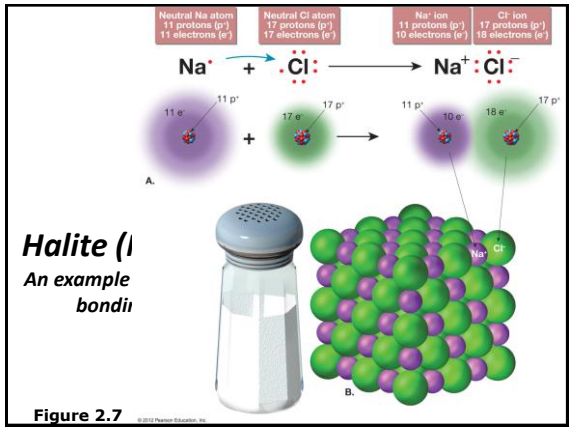


Figure 2.4 A/B

Composition of Minerals

- **Chemical bonding**
  - Formation of a compound by combining two or more elements.
  - 3 main types of bonding
- **Ionic bonding**
  - Atoms gain or lose outermost (valence) electrons to form ions
  - Ionic compounds consist of an orderly arrangement of oppositely charged ions



Halite (

An example
bondi

Figure 2.7

Composition of Minerals

- **Covalent bonding**
  - Atoms share electrons to achieve electrical neutrality
  - Covalent compounds are generally stronger than ionic bonds
  - Both ionic and covalent bonds typically occur in the same compound (bonds are seldom 100 percent ionic or covalent in character)

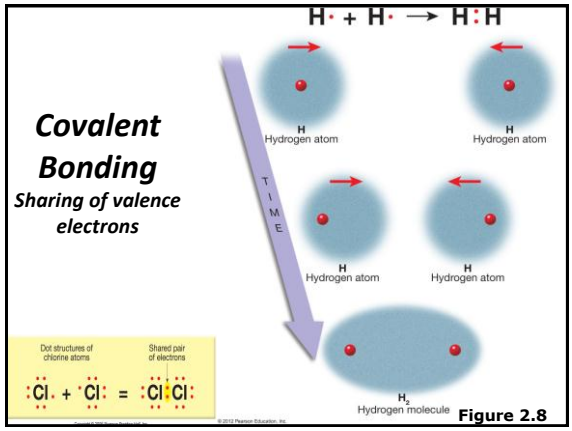


Figure 2.8

Composition of Minerals

- **Other types of bonding**
  - **Metallic bonding**
    - Valence electrons are free to migrate among atoms
    - Weaker and less common than ionic or covalent bonds
    - This type of bonding is why gold is malleable

Composition of Minerals

- **Isotopes and radioactive decay**
  - **Mass number** is the sum of neutrons plus protons in an atom
  - An **isotope** is an atom that exhibits variation in its mass number (same # protons with different # neutrons)
  - Some isotopes have unstable nuclei that emit particles and energy in a process known as **radioactive decay**

Structure of Minerals

- Minerals consist of an orderly array of atoms chemically bonded to form a particular crystalline structure
- For ionic compounds, the internal atomic arrangement is primarily determined by the size of ions involved

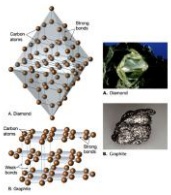
Structure of Minerals

- **Polymorphs**
  - Two or more minerals with the same chemical composition but different crystalline structures
  - Diamond and graphite are good examples of polymorphs
    - The transformation of one polymorph to another is called a **phase change**

Physical Properties of Minerals

- **Crystal form**
  - External expression of the orderly internal arrangement of atoms
  - Crystal growth is often interrupted because of competition for space and rapid loss of heat

Diamond and graphite – polymorphs of carbon



Physical properties of minerals

- **Crystal Form**

External expression of the orderly internal arrangement of atoms.

Crystal growth is often interrupted because of competition for space and rapid loss of heat.

Figure 2.1

Physical Properties of Minerals

- **Luster**
  - Appearance of a mineral in reflected light
  - Two basic categories
    - **Metallic**
    - **Nonmetallic**
  - Other terms are used to further describe luster such as vitreous, silky, waxy, or earthy. This is NOT texture.

Galena (PbS)

Displays metallic luster

Figure 2.9

Physical Properties of Minerals

- **Color**
  - Generally an unreliable diagnostic property to use for mineral identification
  - Often highly variable for a given mineral due to slight changes in mineral chemistry (elemental substitution)
  - Exotic colorations of some minerals produce gemstones

Figure 2.10

Physical Properties of Minerals

- **Streak**
  - Color of a mineral in its powdered form
  - Helpful in distinguishing different forms of the same mineral
- **Hardness**
  - Resistance of a mineral to abrasion or scratching
  - All minerals are compared to a standard scale called the Mohs scale of hardness

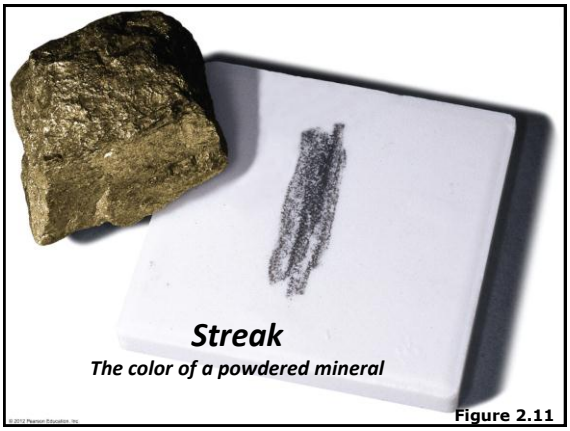


Figure 2.11

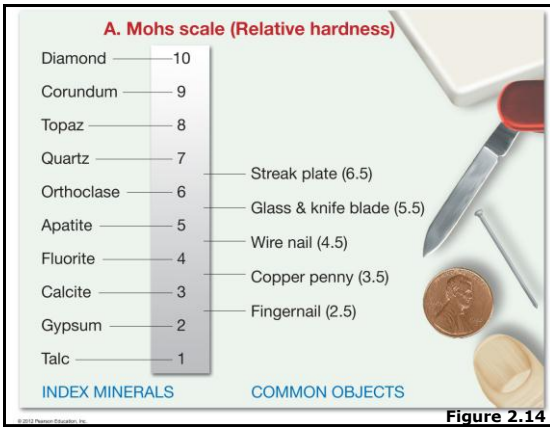


Figure 2.14

Physical Properties of Minerals

- **Cleavage**
  - Tendency to break along planes of weak bonding
  - Produces flat, shiny surfaces
  - Described by resulting geometric shapes
    - Number of planes
    - Angles between adjacent planes

Figure 2.15

Common Cleavage Directions

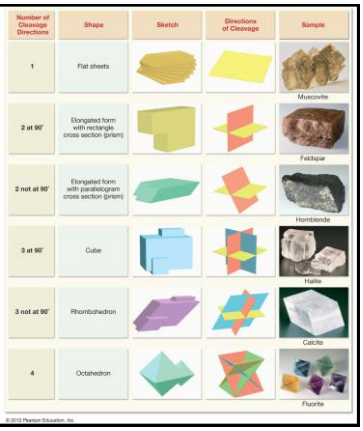
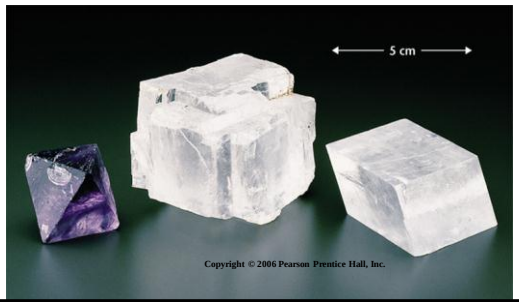


Figure 2.16

Three examples of perfect cleavage – fluorite, halite, and calcite



Physical Properties of Minerals

- **Fracture**
  - Absence of cleavage when a mineral is broken and exhibits non-similar, random, geometric shapes.
- **Specific gravity**
  - Ratio of the weight of a mineral to the weight of an equal volume of water
  - Average value is approximately 2.7

Figure 2.17

Physical Properties of Minerals

- **Other properties**
  - Magnetism
  - Reaction to hydrochloric acid
  - Malleability
  - Double refraction
  - Taste
  - Smell
  - Elasticity
  - Striations
  - Feel (NOT texture)

Figure 2.18 & 2.19

Classification of Minerals

- Nearly 4000 minerals have been identified on Earth
- Rock-forming minerals
  - Common minerals that make up most of the rocks of Earth's crust
  - Only a few dozen members
  - Composed mainly of the 8 elements that make up over 98 percent of the continental crust

Elemental Abundances in Continental Crust

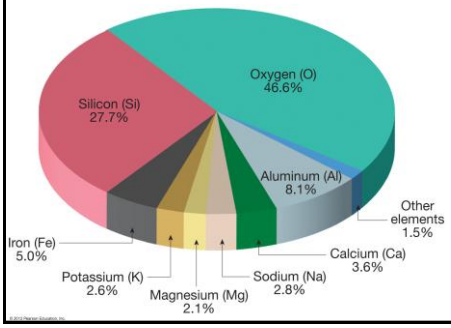


Figure 2.20

Classification of Minerals

- Silicates
  - Most important mineral group
    - Comprise most of the rock-forming minerals
    - Very abundant due to large amounts of silicon and oxygen in Earth's crust
  - Basic building block is the silicon–oxygen tetrahedron molecule
    - Four oxygen ions surrounding a much smaller silicon ion

Two Illustrations of the Si–O Tetrahedron

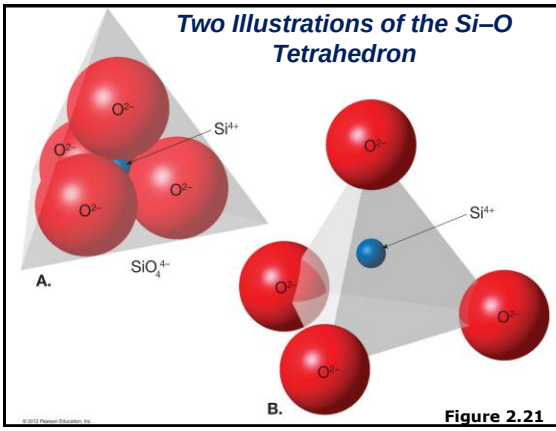


Figure 2.21

Classification of Minerals

- Silicate structures
  - Single tetrahedra are linked together to form various structures including
    - Isolated tetrahedra (ex- olivine)
    - Ring structures (ex- beryl)
    - Single- and double-chain structures (single, ex- pyroxene) (double, ex- amphibole)
    - Sheet or layered structures (ex- mica)
    - Complex three-dimensional structures (ex- quartz)

Classification of Minerals

- Common silicate minerals
  - Olivine
    - High-temperature Fe-Mg silicate
    - Individual tetrahedra linked together by iron and magnesium ions
    - Forms small, rounded crystals with no cleavage

Figure 2.24

Classification of Minerals

- Common silicate minerals
  - Pyroxene group
    - Single chain structures involving iron and magnesium
    - Two distinctive cleavages at nearly 90 degrees
    - Augite is the most common mineral in the pyroxene group
    - Blackish-green color

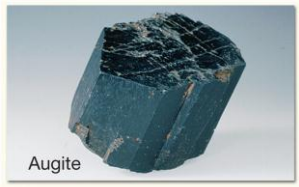


Figure 2.24

Classification of Minerals

- Common silicate minerals
  - Amphibole group
    - Double-chain structures involving a variety of ions
    - Two perfect cleavages exhibiting angles of 124 and 56 degrees
    - Hornblende is the most common mineral in the amphibole group
    - Blackish-brown color

Hornblende Crystals

Figure 2.24

Classification of Minerals

- Common silicate minerals
  - Mica Group
    - Sheet structures that result in one direction of perfect cleavage
    - Biotite is the common dark-colored mica mineral
    - Muscovite is the common light-colored mica mineral

Figure 2.24

Classification of Minerals

- Common silicate minerals
  - Feldspar group
    - Most common mineral group
    - Three-dimensional framework of tetrahedra exhibit two directions of perfect cleavage at 90 degrees
    - Orthoclase (potassium feldspar) and plagioclase (sodium and calcium feldspar) are the two most common members

Potassium Feldspar

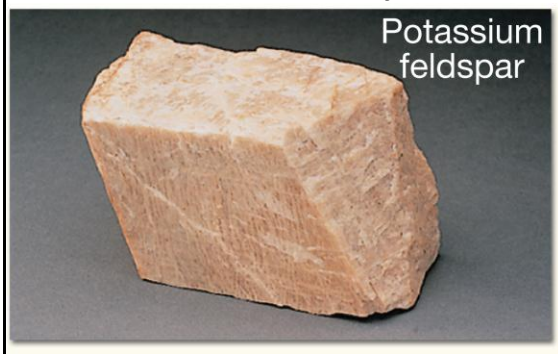


Figure 2.24

Striations on Plagioclase Feldspar

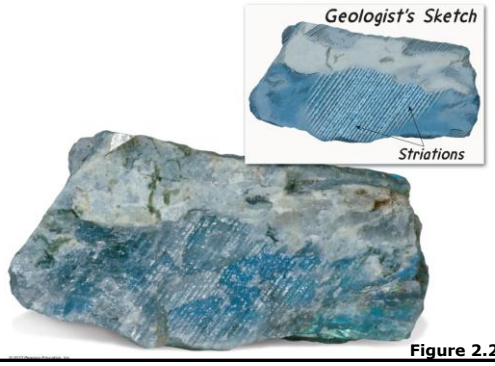


Figure 2.26

Classification of Minerals

- Common silicate minerals
  - Clay minerals
    - Clay is a general term used to describe a variety of complex minerals
    - Clay minerals all have a sheet or layered structure
    - Most originate as products of chemical weathering

Classification of Minerals

- Important nonsilicate minerals
  - Several major groups exist including
    - Oxides (mined for iron)
    - Sulfides (mined for zinc and lead)
    - Sulfates (mined for gold and silver)
    - Native elements
    - Carbonates (calcite and dolomite)
    - Halides (salts)
    - Phosphates

Classification of Minerals

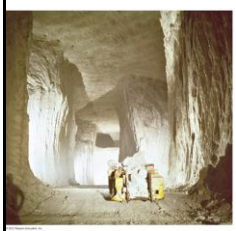
- Important nonsilicate minerals
  - Carbonates
    - Primary constituents in limestone and dolostone
    - Calcite (calcium carbonate) and dolomite (calcium-magnesium carbonate) are the two most important carbonate minerals
  - Halite and Gypsum
    - Evaporite minerals
    - Important nonmetallic resources

Classification of Minerals

- Important nonsilicate minerals
  - Many nonsilicate minerals have economic value
  - Examples
    - Hematite (oxide mined for iron ore)
    - Halite (halide mined for salt)
    - Sphalerite (sulfide mined for zinc ore)
    - Native Copper (native element mined for copper)

Mineral Resources

The endowment of useful minerals ultimately available commercially



- Mineral resources include
  - Reserves – already identified deposits
  - Known deposits that are not yet economically or technologically recoverable

Figure 2.27

Mineral Resources

- **Ore**
  - **A useful metallic mineral that can be mined at a profit**
  - **Must be concentrated above its average crustal abundance**
  - **Profitability may change because of economic changes**

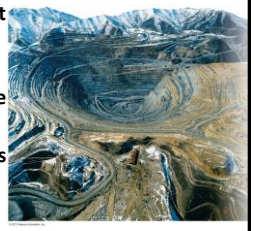


Figure 2.29

End of Chapter 2