1 ***Matter and Minerals***

***Earth***
***Chapter 3***

2 **Minerals: summary in haiku form**

"Mineral" defined:
natural, inorganic,
solid (and two more).

continued...

Also crystalline,
chemically specific.
There! I fit it in!

3 ***Figure 3.1***

4 **Minerals: Building Blocks of Rocks**

- Definition of a Mineral:
  - Naturally occurring
  - Generally inorganic
  - Solid substance
  - Orderly crystalline structure
  - Definite chemical composition
- Definition of a Rock:
  - A solid mass of minerals or mineral-like matter that occurs naturally
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5 **Atoms: Building Blocks of Minerals**

- Atoms
  - Smallest particles of matter that cannot be chemically split
  - Composed of:
    - Protons: charge of +1
    - Neutrons: charge of 0
    - Surrounded by electrons: charge of –1
      - Electrons exist as a cloud of negative charges surrounding the nucleus of protons and neutrons, called principal shells
      - The outermost shell contains valence electrons, which interact with other atoms to or chemical bonds

6 **The Atom**

7 **Atoms: Building Blocks of Minerals**

- Atomic Number
  - The number of protons in the nucleus of an atom
  - Determines the atom's chemical nature
- Element
  - A group of the same kind of atoms
  - Approximately 90 natural elements and several synthesized in a laboratory
  - Organized in a periodic table so that those with similar properties line up
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    -
    -

8 **The Periodic Table**

9 **Why Atoms Bond**

- Chemical Bonding
  - Formation of a compound by combining two or more elements

- Transferring or sharing electrons that allows each atom to attain a full valence shell of electrons
- Octet Rule: Atoms tend to gain, lose, or share electrons until they are surrounded by eight valence electrons

10 **Why Atoms Bond**

- Ionic Bonding
  - Atoms gain or lose outermost (valence) electrons to form ions (positively and negatively charged atoms).
  - Ionic compounds consist of an orderly arrangement of oppositely charged ions.
  - Ionic bond: the attraction of oppositely charged ions to one another
  - Examples include:
    - Halite (table salt)—NaCl

11 **Halite (NaCl)—An Example of Ionic Bonding**

12 **Composition of Minerals**

- Covalent Bonding
  - Atoms share a pair of electrons

13 **Composition of Minerals**

- Other Types of Bonding:
- Metallic Bonding
  - Valence electrons are free to migrate among atoms
  - Accounts for the high electrical conductivity of metals
- Hybrid Bonds
  - Many chemical bonds are actually hybrids that exhibit some degree of electron sharing and some degree of electron transfer

14 **How Do Minerals Form?**

- Precipitation of Mineral Matter
  - Ions dissolved in an aqueous solution reach saturation and start forming crystalline solids
  - A drop in temperature or water loss through evaporation can cause ions to reach saturation

15 **How Do Minerals Form?**

- Crystallization of Molten Rock
  - Similar to water freezing
  - When the magma is hot, the atoms are mobile When the magma cools, the atoms slow and begin to chemically combine
- Deposition as a Result of Biological Process
  - Marine organisms secrete calcium carbonate ($CaCO_3$)

16 **How Do Minerals Form?**

17 **Physical Properties of Minerals**

- Primary Diagnostic Properties
  - Determined by observation or performing a simple test
  - Several physical properties are used to identify hand samples of minerals

18 **Physical Properties of Minerals**

- Optical Properties
  - Luster
    - Appearance of a mineral in reflected light
  - Two basic categories:
    - Metallic

- Nonmetallic
  - Includes vitreous or glassy luster, dull or earthy luster, pearly luster, silky luster, greasy luster

19 **Submetallic and Metallic Luster of Galena (PbS)**

20 **Physical Properties of Minerals**

- Optical Properties
  - Ability to transmit light
    - Opaque—no light is transmitted
    - Translucent—light, but no image is transmitted
    - Transparent—light and an image are visible through the sample

21 **Physical Properties of Minerals**

- Optical Properties
  - Color
    - Generally unreliable for mineral identification
    - Often highly variable due to impurities or slight changes in mineral chemistry

22 **Color Variations in Minerals**

23 **Physical Properties of Minerals**

- Optical Properties
  - Streak
    - Color of a mineral in its powdered form
    - Not every mineral produces a streak when rubbed across a streak plate

24 **Streak Is Obtained on an Unglazed Porcelain Plate**

25 **Physical Properties of Minerals**

- Crystal Shape or Habit
  - Characteristic shape of a crystal or aggregate of crystals

26 **Common Crystal Habits**

27 **Physical Properties of Minerals**

- Crystal Shape, or Habit
  - Mineral strength
    - How easily minerals break or deform under stress
  - Tenacity
    - The mineral's resistance to breaking or deforming
      - Brittle minerals (such as those with ionic bonds) will shatter into small pieces
      - Malleable minerals (such as those with metallic bonds) are easily hammered into different shapes
      - Sectile minerals, such as gypsum and talc, can be cut into thin shavings
      - Elastic minerals, such as the micas, will bend and snap back to their original shape

28 **Physical Properties of Minerals**

- Crystal Shape, or Habit
  - Hardness
    - Resistance of a mineral to abrasion or scratching
    - All minerals are compared to a standard scale called the Mohs scale of hardness

29

30 **Physical Properties of Minerals**

- Crystal Shape, or Habit
  - Cleavage
    - Tendency to break along planes of weak bonding
    - Produces smooth, flat surfaces
    - Described by:
      - Number of planes
      - Angles between adjacent planes

–Resulting geometric shapes

31

32 **Micas Exhibit Perfect Cleavage**

33 **Physical Properties of Minerals**

- Crystal Shape, or Habit
  - Fracture
    - Absence of cleavage when a mineral is broken
      - –Irregular fractures
      - –Conchoidal fractures
      - –Splintery fractures
      - –Fibrous fractures
    -

34 **Irregular Versus Conchoidal Fracture**

35 **Physical Properties of Minerals**

- Density and Specific Gravity
  - Density is defined as mass per unit volume
  - Specific gravity is ratio of the weight of a mineral to the weight of an equal volume of water
    - Most minerals have a specific gravity between 2 and 3
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36 **Physical Properties of Minerals**

- Other Properties:
  - Taste
    - Halite tastes like salt
  - Feel
    - Talc feels soapy
    - Graphite feels greasy
  - Magnetism
    - Magnetite can be picked up by a magnet
    - Lodestone is a natural magnet

37 **Rock Salt (halite, NaCl)**

38 **Physical Properties of Minerals**

- Other Properties:
  - Optical properties
    - Calcite has double refraction
  - Reaction to dilute hydrochloric acid
    - Carbonates will effervesce in acid

39 **Optical Calcite**

40 **Effervescence in HCl**

41 **Mineral Structures and Compositions**

- All mineral samples are crystal or crystalline solids
  - Any natural solid with orderly, repeating internal structures

42 **Mineral Structures and Compositions**

- Mineral Structures
  - Unit cells
    - Atomic arrangement that results in the basic building blocks of a mineral crystal
  - Minerals can be constructed of the same unit cells and have different external forms
    - Examples of minerals with cubic unit cells include:
      - –Fluorite—crystals are cubes
      - –Magnetite—crystals are octahedrons
      - –Garnets—crystals are dodecahedrons

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43 **Cubic Unit Cells**

44 **Mineral Structures and Compositions**

- Mineral Structures
  - Steno's Law or Law of Constancy of Interfacial Angles
    - Regardless of crystal size, the angles between equivalent crystal faces of the same mineral are consistent

45 **Mineral Structures and Compositions**

- Compositional Variations in Minerals
  - Ions of similar size can substitute for one another without disrupting the mineral's internal framework
    - Examples include olivine: (Mg, Fe)$SiO_2$

46 **Mineral Structures and Compositions**

- Compositional Variations in Minerals
  - Other minerals have trace variations in their chemical compositions
    - Examples include quartz ($SiO_2$) and fluorite ($CaF_2$)
  - The trace variations can significantly influence the mineral's color

47 **Mineral Structures and Compositions**

- Structural Variations in Minerals
  - Polymorphs
    - Minerals with the same composition but different crystalline structures
    - Examples include diamond and graphite
- Transforming one polymorph into another is called a phase change

48 **Diamond Versus Graphite—**
**Polymorphs of Carbon**

49 **How Minerals Are Classified**

- Nearly 4000 minerals have been named
- Rock-Forming Minerals
  - Only a few dozen
  - Common minerals that make up most of the rocks of Earth's crust
  - Composed mainly of the eight elements that make up most of the continental crust
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50 **The Eight Most Abundant Elements in the Continental Crust**

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52 **How Minerals Are Classified**

- Classifying Minerals
  - A collection of specimens that exhibit similar internal structure and chemical compositions are called mineral species
  - Mineral species are then further divided into mineral varieties
    - Examples of varieties of quartz
      - –Smoky quartz: contains trace amounts of aluminum
      - –Amethyst: contains trace amounts of iron
- Mineral species are assigned to mineral classes
  - Silicates, carbonates, halides, and sulfates are different mineral classes

53 **How Minerals Are Classified**

- Silicate Versus Nonsilicate Minerals
  - Silicate minerals are the most common type of minerals
    - Account for >90% of Earth's crust
    - Silicon and oxygen make up the basic building blocks of silicate minerals
  - Nonsilicate minerals are not as common as the silicates but important economically

54 **The Silicates**

- All silicate minerals contain oxygen and silicon—the two most abundant elements in Earth's

crust
- Silicate Structures
  - Silicon–oxygen tetrahedron
    - Fundamental building block
    - Four oxygen ions surrounding a much smaller silicon ion
  - Single tetrahedra are linked together to form various structures
  -
    -

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56 **The Silicates**

- Silicate Structures
  - Minerals with independent tetrahedra
    - Oxygen ions are bonded with positive ions (such as $Mg^{2+}$, $Fe^{2+}$, $Ca^{2+}$)
    - Examples include:
      - Olivine
      - Garnet
    - Form hard, dense equidimensional crystals that lack cleavage

57 **The Silicates**

- Silicate Structures
  - Minerals with chain or sheet structures
    - Polymerization—the $SiO_4$ tetrahedra can link to one another in a variety of configurations
      - Accounts for the high variety of silicate minerals
    - Tetrahedra can form single chains, double chains, and sheet structures
      - Some oxygen ions are "shared" between tetrahedra

58 **The Silicates**

- Silicate Structures
  - Minerals with three-dimensional framework
    - All oxygen ions are "shared" between tetrahedra
    - Examples include:
      - Quartz
      - The feldspars
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60 **The Silicates**

- Joining Silicate Structures
  - Most silicate minerals have a net negative charge (except for quartz)
  - Metal ions are required to balance the charge
  - These positive ions bond with unshared oxygen ions in the tetrahedra
    - Most common ions are $Fe^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$, $Al^{3+}$, $Ca^{2+}$

61 **The Silicates**

- Joining Silicate Structures
  - Covalent silicon–oxygen bonds are typically stronger than the ionic bonds of the silicate structure
  - Controls the cleavage and hardness of minerals
    - Examples:
      - Quartz has a three-dimensional framework, is very hard, and lacks cleavage
      - Talc has a sheet structure framework bonded with Mg ions and is a very soft mineral

62 **Common Silicate Minerals**

- The feldspars are the most common silicate group and make up more than 50 percent of Earth's crust

- Quartz is the second-most abundant mineral in the continental crust and the only common mineral made completely of silicon and oxygen
  –

63 **Common Silicate Minerals**

64 **Common Silicate Minerals**

- The Light (Nonferromagnesium) Silicates
  - Generally light in color
  - Have a specific gravity of approximately 2.7
  - Contain varying amounts of aluminum, potassium, calcium, and sodium
  - Lacking iron and magnesium
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65 **Common Silicate Minerals**

- The Light Silicates
  - Feldspar group
    - Most common mineral group
    - Forms under a wide range of temperatures and pressures
    - Exhibit two directions of perfect cleavage at 90 degrees
    - Two most common members:
      –Orthoclase (potassium feldspar)
      –Plagioclase (sodium and calcium feldspar)
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- 
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66 **Feldspar Minerals**

67 ***Potassium feldspar***

68 ***Plagioclase feldspar***

69 **Common Silicate Minerals**

- The Light Silicates
  - Quartz
    - Only common silicate composed entirely of oxygen and silicon
    - Hard and resistant to weathering
    - Conchoidal fracture
    - Often forms hexagonal crystals
    - Colored by impurities (various ions)

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72 **Common Silicate Minerals**

- The Light Silicates
  - Muscovite
    - Common member of the mica family
    - Excellent cleavage in one direction
    - Thin sheets are clear
      –Used as glass during the Middle Ages
    - Produces the "glimmering" brilliance often seen in beach sand

73 **Common Silicate Minerals**

- The Light Silicates
  - Clay minerals
    - "Clay" is a general term used to describe a variety of complex minerals that have sheet structure
    - Clay makes up a large percentage of soil
    - Most originate as products of chemical weathering
    - Kaolinite is common clay mineral used to manufacture fine china

74 **Common Silicate Minerals**

- The Dark (Ferromagnesium) Silicates
  - Contain iron and/or magnesium in their structure
  - Generally dark in color
  - Have a specific gravity between 3.2 and 3.6

75 **Common Silicate Minerals**

- The Dark Silicates
  - Olivine group
    - High-temperature silicates
    - Black to green in color
    - Glassy luster and conchoidal fracture
    - Forms small, rounded crystals

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- The Dark Silicates
  - Pyroxene group
    - Important components of dark-colored igneous rocks
    - Augite is the most common mineral in the pyroxene group
      - Black in color
      - Two distinctive cleavages at nearly 90 degrees
      - Dominant mineral in basalt

78 **Common Silicate Minerals**

- The Dark Silicates
  - Amphibole group
    - Hornblende is the most common mineral in this group
    - Two perfect cleavages exhibiting angles of 120 and 60 degrees
      -

79 **Augite and Hornblende**

80 ***Hornblende, an amphibole***

81 ***Cleavage angles for augite and hornblende***

82 **Common Silicate Minerals**

- The Dark Silicates
  - Biotite
    - Iron-rich member of the mica family
    - Excellent cleavage in one direction
  - Garnet
    - Composed of individual tetrahedra linked by metallic ions (similar to olivine)
    - Glassy luster and conchoidal fracture

83 **Important Nonsilicate Minerals**

- Divided into groups based on the negatively charged ion or complex ion that the members have in common
- Make up approximately 8 percent of Earth's crust
  -

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85 **Important Nonsilicate Minerals**

- Carbonates
  - Composed of the carbonate ion ($CO_3^{2-}$) and a positive ion
  - Two most common carbonates are calcite ($CaCO_3$) and dolomite $CaMg(CO_3)_2$
  - Primary constituents in limestone and dolostone
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86 **Important Nonsilicate Minerals**

- Many nonsilicate minerals have economic value
  - Examples:
    - Halite (mined for salt)
    - Gypsum (used to make building materials)
    - Hematite and magnetite (mined for iron ore)
    - Native elements (gold, silver, and diamonds)

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87 **Important Nonsilicate Minerals**

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91 ***Native copper***

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95 **End of Chapter**