MINERALS OF THE EARTH'S CRUST

Chapter 5

Standards

SES2d. Associate specific plate tectonic settings with the production of particular groups of igneous and metamorphic rocks and mineral resources

SES3d. Explain the processes that transport and deposit material in terrestrial and marine sedimentary basins, which result, over time, in sedimentary rock.

Characteristics of Minerals

- To be a mineral, a substance must have four characteristics:
  - it must be inorganic—it cannot be made of or by living things;
  - it must occur naturally—it cannot be man-made;
  - it must be a crystalline solid;
  - it must have a consistent chemical composition.

Characteristics of Minerals, *continued*

The diagram below shows the four characteristics of minerals.

Questions to Identify a Mineral	Coal	Brass	Obsidian	Basalt	Fluorite
					
Is it inorganic?	No	**Yes**	**Yes**	**Yes**	**Yes**
Does it occur naturally?		No	**Yes**	**Yes**	**Yes**
Is it a crystalline solid?			No	**Yes**	**Yes**
Does it have a consistent chemical composition?				No	**Yes**

Kinds of Minerals

- The 20 most common minerals are called *rock-forming minerals* because they form the rocks that make up Earth's crust.
  - Ten minerals are so common that they make up 90% of Earth's crust. These minerals are quartz, orthoclase, plagioclase, muscovite, biotite, calcite, dolomite, halite, gypsum, and ferromagnesian minerals.

- All minerals can be classified into two main groups—silicate minerals and nonsilicate minerals—based on their chemical compositions.

Kinds of Minerals, *continued*

Silicate Minerals

- **silicate mineral** a mineral that contains a combination of silicon and oxygen, and that may also contain one or more metals

- Common silicate minerals include quartz, feldspars, micas ,and ferromagnesian minerals, such as amphiboles, pyroxenes, and olivines.

- Silicate minerals make up 96% of Earth's crust. Quartz and feldspar alone make up more than 50% of the crust.

Kinds of Minerals, *continued*

Nonsilicate Minerals

- **nonsilicate mineral** a mineral that does not contain compounds of silicon and oxygen
- Nonsilicate minerals comprise about 4% of Earth's crust.
- Nonsilicate minerals are organized into six major groups based on their chemical compositions.
- The six major groups of nonsilicate minerals are carbonates, halides, native elements, oxides, sulfates, and sulfides.

Crystalline Structure

- Each type of mineral is characterized by a specific geometric arrangement of atoms, or its ***crystalline structure.***
- **crystal** a solid whose atoms, ions, or molecules are arranged in a regular, repeating pattern
- One way that scientists study the structure of crystals is by using X rays. X rays that pass through a crystal and strike a photographic plate produce an image that shows the geometric arrangement of the atoms in the crystal.

Crystalline Structure of Silicate Minerals

- Even though there are many kinds of silicate minerals, their crystalline structure is made up of the same basic building blocks—silicon-oxygen tetrahedra.

- **silicon-oxygen tetrahedron** the basic unit of the structure of silicate minerals; a silicon ion chemically bonded to and surrounded by four oxygen ions

Isolated Tetrahedral Silicates

- In minerals that have isolated tetrahedra, only atoms other than silicon and oxygen atoms like silicon-oxygen tetrahedra together.

- Olivine is an isolated tetrahedral silicate.

Crystalline Structure of Silicate Minerals, *continued*

The diagram below shows the tetrahedral arrangement of isolated tetrahedral silicate minerals.

Isolated tetrahedra do not link with other silicon or oxygen atoms.

Crystalline Structure of Silicate Minerals, *continued*

Ring Silicates

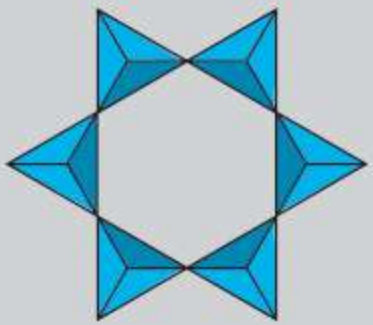
- Ring silicates form when shared oxygen atoms join the tetrahedra to form three-, four-, or six-sided rings.
- Beryl and tourmaline are ring silicates.

Single-Chain Silicates

- In single-chain silicates, each tetrahedron is bonded to two others by shared oxygen atoms.
- Most double-chain silicates are called *pyroxenes*.

Crystalline Structure of Silicate Minerals, *continued*

The diagram below shows the tetrahedral arrangement of ring silicate minerals.

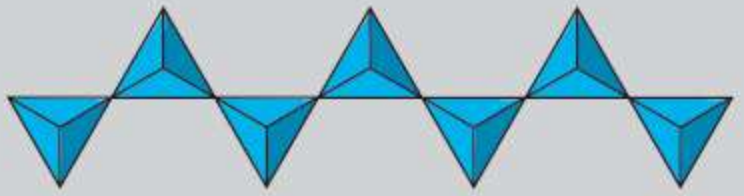


Ring silicates form rings by sharing oxygen atoms.

Crystalline Structure of Silicate Minerals, *continued*

The diagram below shows the tetrahedral arrangement of single-chain silicate minerals.

Single-chain silicates form a chain by sharing oxygen atoms.



Crystalline Structure of Silicate Minerals, *continued*

Double-Chain Silicates

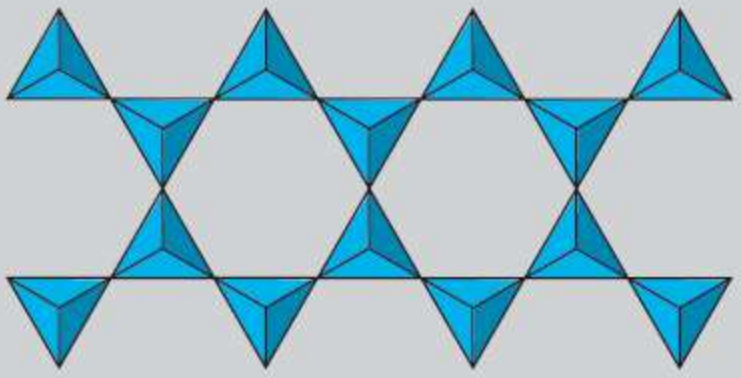
- In double-chain silicates, two single chains of tetrahedra bond to each other.
- Most double-chain silicates are called *amphiboles*.

Sheet Silicates

- In the sheet silicates, each tetrahedron shares three oxygen atoms with other tetrahedra. The fourth oxygen atom bonds with an atom of aluminum or magnesium, which joins the sheets together.
- The mica minerals, such as muscovite and biotite, are sheet silicates.

Crystalline Structure of Silicate Minerals, *continued*

The diagram below shows the tetrahedral arrangement of double-chain silicate minerals.

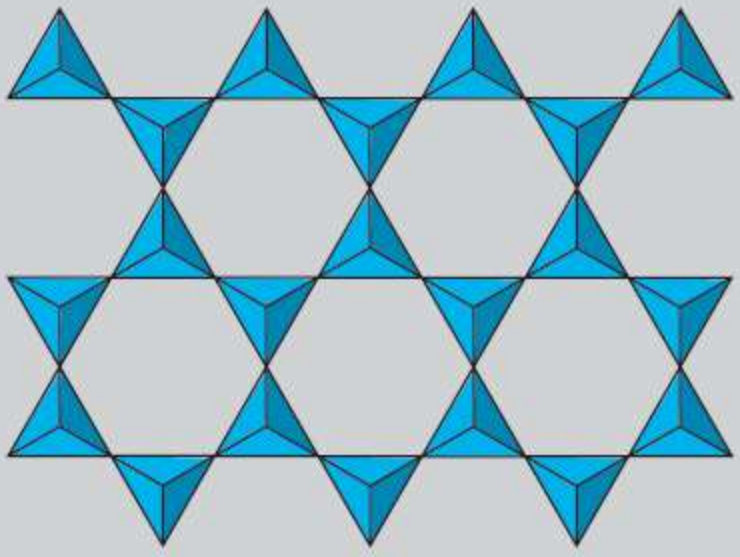


Double-chain silicates form when two single-chains of tetrahedra bond to each other.

Crystalline Structure of Silicate Minerals, *continued*

The diagram below shows the tetrahedral arrangement of sheet silicate minerals.

Sheet silicates form when each tetrahedron shares three of its oxygen atoms with other tetrahedra.



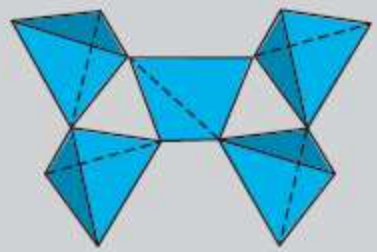
Crystalline Structure of Silicate Minerals, *continued*

Framework Silicates

- In the framework silicates, each tetrahedron is bonded to four neighboring tetrahedra to form a three-dimensional network.
- Frameworks that contain only silicon-oxygen tetrahedra are the mineral quartz.
- Other framework silicates contain some tetrahedra in which atoms of aluminum or other metals substitute for some of the silicon atoms.
- Quartz and feldspars are framework silicates.

Crystalline Structure of Silicate Minerals, *continued*

The diagram below shows the tetrahedral arrangement of framework silicate minerals.



Framework silicates form when each tetrahedron is bonded to four other tetrahedra.

Crystalline Structure of Nonsilicate Minerals

- Because nonsilicate minerals have diverse chemical compositions, nonsilicate minerals display a vast variety of crystalline structures.
- Common crystalline structures for nonsilicate minerals include cubes, hexagonal prisms, and irregular masses.
- The structure of a nonsilicate crystal determines the mineral's characteristics.
- In the crystal structure called *closest packing*, each metal atom is surrounded by 8 to 12 other metal atoms that are as close to each other as the charges of the atomic nuclei will allow.

Physical Properties of Minerals

Color

- While color is a property that is easily observed, it is unreliable for the identification of minerals.
- The color of a mineral sample can be affected by the inclusion of impurities or by weathering processes.

Streak

- **streak** the color of a mineral in powdered form
- Streak is more reliable than color for the identification of minerals.
- Streak is determined by rubbing some of the mineral against an unglazed ceramic tile called a *streak plate*.

Physical Properties of Minerals, *continued*

Luster

- **luster** the way in which a mineral reflects light
- A mineral is said to have a metallic luster if the mineral reflects light as a polished metal does.
- All other minerals have nonmetallic luster.
- There are several types of nonmetallic luster, including glassy, waxy, pearly, brilliant, and earthy.

Physical Properties of Minerals, *continued*

Cleavage and Fracture

- **cleavage** in geology, the tendency of a mineral to split along specific planes of weakness to form smooth, flat surfaces
- **fracture** the manner in which a mineral breaks along either curved or irregular surfaces
- *Uneven* or *irregular fractures* have rough surfaces.
- *Splintery* or *fibrous fractures* look like a piece of broken wood.
- Curved surfaces are *conchoidal fractures* .

Physical Properties of Minerals, *continued*

Hardness

- The measure of the ability of a mineral to resist scratching is called *hardness*. Hardness does not mean "resistance to cleavage or fracture."
- The hardness of a mineral can be determined by comparing the mineral to minerals of Mohs hardness scale.
- **Mohs hardness scale** the standard scale against which the hardness of minerals is rated.
- The strength of the bonds between the atoms that make up a mineral's internal structure determines the hardness of a mineral.

Physical Properties of Minerals, *continued*

The diagram below shows Mohs Hardness Scale.

Mohs Hardness Scale

Mineral	Hardness	Common test	Mineral	Hardness	Common test
Talc	1	easily scratched by fingernail	Feldspar	6	scratches glass, but does not scratch steel
Gypsum	2	can be scratched by fingernail	Quartz	7	easily scratches both glass and steel
Calcite	3	barely can be scratched by copper penny	Topaz	8	scratches quartz
Fluorite	4	easily scratched with steel file or glass	Corundum	9	scratches topaz
Apatite	5	can be scratched by steel file or glass	Diamond	10	scratches everything

Physical Properties of Minerals, *continued*

Crystal Shape

- A mineral crystal forms in one of six basic shapes.
- A certain mineral always has the same general shape because the atoms that form the mineral's crystals always combine in the same geometric pattern.
- The six basic crystal systems are the isometric or cubic system, the orthorhombic system, the tetragonal system, the hexagonal system, the monoclinic system, and the triclinic system.

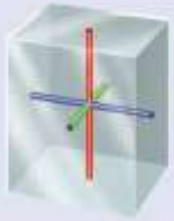
Physical Properties of Minerals, *continued*

The diagram below shows the six basic crystal systems.

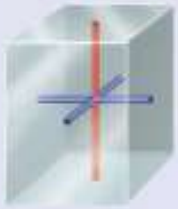
The Six Basic Crystal Systems

Isometric or Cubic System
Three axes of equal length intersect at 90° angles.

Orthorhombic System
Three axes of unequal length intersect at 90° angles.

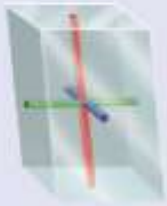


Tetragonal System
Three axes intersect at 90° angles. The two horizontal axes are of equal length. The vertical axis is longer or shorter than the horizontal axes

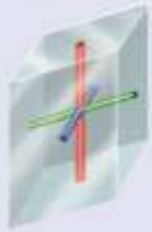


Hexagonal System
Three horizontal axes of the same length intersect at 120° angles. The vertical axis is longer or shorter than the horizontal axes.

Monoclinic System
Two of the three axes of unequal length intersect at 90° angles. The third axis is oblique to the others.



Triclinic System
Three axes of unequal length are oblique to one another.



Physical Properties of Minerals, *continued*

Density

- **density** the ratio of the mass of a substance to the volume of a substance; commonly expressed as grams per cubic centimeter for solids

- The density of a mineral depends on the kinds of atoms in the mineral and on how closely the atoms are packed.

$$density = mass \div volume$$

Special Properties of Minerals

- A few minerals have some additional, special properties that can help identify those minerals.

Fluorescence and Phosphorescence

- The ability to glow under ultraviolet light is called *fluorescence*.
- Fluorescent minerals absorb ultraviolet light and then produce visible light of various colors.
- The property of some minerals to glow after the ultraviolet light is turned off is called *phosphorescence*.

Special Properties of Minerals, *continued*

Chatoyancy and Asterism

- In reflected light, some minerals display a silky appearance that is called *chatoyancy*, or the *cat's-eye effect*.
- A similar effect called *asterism* is the phenomenon in which a six-sided star appears when a mineral reflects light.

Double Refraction

- The property of some minerals, particularly some forms of calcite, to produce a double image of any object viewed through the mineral is called *double refraction*.

Special Properties of Minerals, *continued*

Magnetism

- Minerals that are attracted to magnets display the property of magnetism. These minerals may be magnetic themselves.
- In general, nonsilicate minerals that contain iron are more likely to be magnetic than silicate minerals are.

Radioactivity

- The property known as radioactivity results as unstable nuclei decay over time into stable nuclei by releasing particles and energy.
- A Geiger counter is used to detect the released particles and, thus, to identify minerals that are radioactive.

Chapter 5

Maps in Action

Rock and Mineral Production in the United States

Commodity	Production value (in billions of dollars)*
1 Stone	8.2
2 Cement	6.3
3 Sand and gravel	5.3
4 Gold	3.0
5 Copper	2.7
6 Iron ore	1.6
7 Phosphate	1.2
8 Lime	1.2
9 Salt	1.1
10 Zinc	1.0
Total production value	31.6

*rounded in hundreds of millions of dollars

Chapter 5

REVIEW

1. Coal is

A. organic and a mineral.
B. inorganic and a mineral.
C. organic and not a mineral.
D. inorganic and not a mineral.

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Chapter 5

REVIEW

2. Which of the following is one of the 10 rock-forming minerals that make up 90% of Earth's crust?

F. quartz
G. fluorite
H. copper
I. talc

Chapter 5

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Chapter 5

REVIEW

3. Minerals can be identified by all of the following properties *except*

A. color.
B. streak.
C. hardness.
D. luster.

Chapter 5

REVIEW

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A. color.

B. streak.

C. hardness.

D. luster.

Chapter 5

REVIEW

4. All minerals in Earth's crust

F. have a crystalline structure.
G. are classified as ring silicates.
H. are classified as pyroxenes or amphiboles.
I. have no silicon in their tetrahedral structure.

Chapter 5

REVIEW

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Chapter 5

REVIEW

5. Which mineral can be scratched by a fingernail that has a hardness of 2.5 on the Mohs scale?

A. diamond
B. quartz
C. topaz
D. talc

Chapter 5

REVIEW

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Chapter 5

REVIEW

6. Carbonates, halides, native elements, oxides, sulfates, and sulfides are classes of what mineral group?

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nonsilicate minerals

Chapter 5

REVIEW

7. What mineral is made up of *only* the elements oxygen and silicon?

Chapter 5

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quartz

Chapter 5

REVIEW

8. What property is a mineral said to have when a person is able to view double images through it?

Chapter 5

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double refraction