**The Earth Through Time**

# Chapter 4—Rocks and Minerals: Documents that Record Earth’s History

#### CHAPTER OUTLINE FOR TEACHING

**I. Minerals**

 **A. Physical Properties of Minerals**

 1. Color

 2. Streak

 3. Luster

 4. Cleavage

 5. Hardness

 6. Density

 7. Crystal habit

 8. Others: magnetism, taste, flexibility, feel, etc.

 **B. Common Rock-Forming Minerals**

 1. Silicate Minerals: have Si and O in their formulas

 a. Quartz

 b. Feldspars: plagioclase and orthoclase

 c. Micas: muscovite and biotite

 d. Amphiboles: hornblende

 e. Pyroxenes: augite

 f. Olivine

 g. Clay minerals

 2. Non-silicate minerals

 a. Carbonates: calcite, dolomite, aragonite

 b. Evaporites: halite, gypsum, anhydrite

 c. Others

**II. Rocks (Great Rock Families)**

 **A. Igneous Rocks**

 1. Cooling history of magma or lava (revealed by texture)

 a. intrusive (plutons, dikes, sills)

 b. extrusive (lava flows, ash falls)

 c. two-stage (porphyritic rocks)

 2. Mineral composition

 a. silica-rich rocks (granite, rhyolite)

 b. intermediate rocks (granodiorite, diorite, andesite)

 c. silica-poor rocks (gabbro, basalt)

 3. Crystallization of magma

 a. first-formed minerals have more perfect shapes

 b. Bowen’s reaction series helps us understand order of mineral formation

 (i) continuous reaction series: feldspar composition changes

 (ii) discontinuous reaction series: iron-rich silicate minerals reacts with liquid

 4. Volcanism (volcanic activity)

 a. basaltic magmas (partial melting of upper mantle)

 b. andesitic magmas (fractional crystallization of melting crust and mixing of basaltic magma and siliceous sediments)

 **B. Sedimentary Rocks**

 1. Lithification: compaction and/or cementation

 2. Ubiquitous structure: layering (stratification)

 3. Derivation by weathering

 a. decomposition (chemical)

 b. disintegration (physical)

 4. Sedimentary textures

 a. clastic

 b. non-clastic

 5. Classification

 a. clastic rocks: conglomerate, breccia, sandstone, siltstone, shale

 b. non-clastic rocks: carbonates (limestone, dolostone), chemical (chert, rock salt), biochemical (coal, chalk)

 c. other sedimentary rocks: chert, evaporites, coal

 **C. Metamorphic Rocks**

 1. Metamorphic processes

 a. regional

 b. contact

 2. Metamorphic index minerals

 a. form under specific temperature and pressure conditions

 b. range from low grade (chlorite) to high grade (sillimanite)

 3. Metamorphic textures and kinds of rocks

 a. foliated: slate, phyllite, schist, gneiss

 b. non-foliated: marble, quartzite, greenstone, hornfels

 4. Classification

 a. foliated rocks: slate, phyllite, schist, gneiss

 b. non-foliated rocks: marble, quartzite, greenstone, hornfels

 5. Metamorphic grades (facies)

 a. show historical significance in terms of past metamorphic conditions of temperature and pressure

 b. delineated by index (metamorphic) minerals

**Answers to Discussion Questions**

1. Minerals are naturally occurring solid, inorganic substances that have a definite chemical composition or range of compositions as well as distinctive properties that reflect the composition and regular internal atomic structure. Minerals have regular internal structures of atoms, unlike amorphous non-crystalline materials like volcanic glass.

2. The eight most abundant chemical elements of the Earth's crust (in order of abundance) are: oxygen (O); silicon (Si); aluminum (Al); iron (Fe); calcium (Ca); sodium (Na); potassium (K); and magnesium (Mg).

3. The silicate minerals are the most common minerals forming about 75% by weight of the Earth's crust. Silicate minerals are important because we live on a silicate world. Silicates are based on silica, a bonding of one silicon atom and four oxygen atoms (the most common elements of the crust). Granite is made of quartz and feldspar, the two most common silicates. Silicate minerals common in sedimentary rocks are quartz, feldspar, mica, and clay.

4. Granite, made of quartz and feldspar, is the rock that best approximates continental crustal composition. Basalt, made of ferromagnesian silicates and plagioclase feldspar, best approximates oceanic crustal composition.

5. Partial melting occurs where pressure is slightly relieved and minerals with select melting points will liquefy and mobilize at the expense of others left behind. In fractional crystallization, some crystals form in the liquid magma as it cools. These crystals fall out or are removed thus making the liquid a different composition. The former generally works to enrich liquids in mafic minerals; the latter to enrich liquids in silicic (lighter) minerals.

6. Grain sizes (crystal sizes) of igneous rocks indicate cooling history: the larger the crystal, the slower the cooling rate. Mixed crystal sizes indicate two stages of cooling. Magmas that have high viscosity generally are relatively low in silica content.

7. In order of increasingly finer grain size, clastic sedimentary rocks are called: conglomerate (or breccia); sandstone; siltstone; and shale (or claystone).

8. Clastic rock grains are most commonly composed of minerals quartz, feldspar, micas, and clay. Clastic rock cements are most commonly calcite, hematite, and quartz. Carbonate rocks are composed mainly of calcite and (or) dolomite. Chert is a finely crystalline form of quartz. Evaporites are composed mainly of halite and (or) gypsum.

9. Chert is a finely crystalline rock that has no cleavage and has hardness near 7. The chert lends itself to flaking and shaping into a spear point and will keep a sharp edge. Limestone can also be finely crystalline rock that has no cleavage, but limestone tends to break along stratification (layering), which can be spaced at small intervals. Limestone is made of calcite, which is a rather soft mineral (H=3). Therefore chert, which is harder, is preferable for an ax head.

10. Marble is rather soft and tends to be finely crystalline and without natural planes of weakness like foliation. Gneiss is much harder due to its silicate mineral content and is strongly foliated, which introduces natural planes of weakness into the rock. Quartzite tends to be more like marble in terms of texture, but is made of a rather hard mineral (quartz), which could be difficult to work with.

11. In order of increasingly common foliation, metamorphic rocks are slate, phyllite, schist, and gneiss.

12. a

13. a

14. a

15. d

16. d

**CHAPTER ACTIVITIES**

**Student activities for in-depth learning:**

1. Select five minerals mentioned in this chapter and do some research on them. Once you have your list, go to the alphabetical list of mineral species at WebMineral.com:

 (http://webmineral.com/Alphabetical\_Listing.shtml). Click on the first letter of the mineral name and find the mineral. Make a list of the main physical properties for your minerals and also make a note of the chemical formula, the origin of the name of the mineral, and some synonyms.

2. Take a look at the picture gallery of sedimentary rocks at Geology.com (http://geology.com/rocks/sedimentary-rocks.shtml). Study the photographs of the sedimentary rocks and read what the page says about them. What are the differences between the three types of sedimentary rocks on that page? Briefly discuss this and how you would distinguish between the three types using observations you could make with your unaided eye.

CHAPTER 4

Rocks and Minerals:

Documents that Record Earth's History 2

WHAT CAN MINERALS TELL US?

Minerals form under specific set of physical conditions (pressure, temperature, and composition). Thus the presents or absents of a mineral informs on the conditions under which they form. 3

WHAT CAN MINERALS TELL US?

1.Radiometric age dating - Minerals containing radioactive elements.

2.Igneous Rocks - Minerals that crystallize from magmas and lavas provide information about temperature, viscosity, composition, type of volcano, and tectonic setting.

WHAT CAN MINERALS TELL US?

3.Metamorphic rocks: Minerals can provide information about temperature, pressure, and composition (both mineral & fluids). From this information which we can determine the depth at which metamorphism occurred, parent rock, and information about the history of the formation of mountain ranges.

WHAT CAN MINERALS TELL US?

4.Sedimentary Rocks: Minerals that form by evaporation in arid climates can tell us about paleoclimatic conditions. Since some climates are controlled by latitude, we can make general inferences about latitude.

5.Sedimentary Rocks: Minerals that form in sea water tell us about the nature of ancient seas and the organisms that lived in them.

WHAT CAN MINERALS TELL US?

6.Sedimentary Rocks: Minerals can provide information on the tectonic setting, amount of relief, paleoclimate, and types of rocks that are eroding in the source area.

7.Sedimentary Rocks: Minerals can also tell us about the changing chemistry of the atmosphere, for example, the presence or absence of oxygen.

WHAT CAN MINERALS TELL US?

8.Igneous/Sedimentary Rocks: Minerals containing iron can record the orientation of the Earth's magnetic field, which yields information on latitude, and provides evidence for drifting continents, sea floor spreading, and movement and reversal of the Earth's magnetic poles.

MINERALS

By definition, minerals are:

1.Naturally occurring

2.Inorganic

3.Solid

4.Definite chemical composition

5.Orderly internal crystal structure

EACH MINERAL HAS UNIQUE SET OF PHYSICAL AND CHEMICAL PROPERTIES, WHICH ALLOW FOR THE IDENTIFICATION OF THE DIFFERENT SPECIES OF MINERALS. MINERALS 10 SOME PHYSICAL PROPERTIES OF MINERALS

color

streak

luster

hardness

density

crystal form

cleavage

fracture

magnetism

reaction to acid

taste

flexibility

feel

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PHYSICAL PROPERTIES OF MINERALS

Color - the color or range of colors of a mineral as it appears to the eye in reflected light.

*Examples*:

Quartz may be colorless, white, pink, purple, dark brown, green or blue.

Malachite is always green.

12

PHYSICAL PROPERTIES OF MINERALS

Luster - the character of the light reflected off of a mineral surface. A mineral may have a metallic luster (looks like polished metal) or a non-metallic luster. Luster is independent of color.

Example:

Galena has a metallic luster

Quartz has a non-metallic luster

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PHYSICAL PROPERTIES OF MINERALS

Streak - the color of a mineral when it is ground to a powder against white unglazed porcelain. Streak color may be quite different from the whole mineral color and is particularly useful for identifying metallic luster minerals

*Examples*:

Hematite may be silver or gray, but it has a reddish brown streak.

Pyrite is gold, but is has a black streak.

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PHYSICAL PROPERTIES OF MINERALS

Hardness - the resistance of a mineral to scratching.

Mohs Hardness Scale is a relative scale from 1 - 10 based on a series of minerals. Talk is the softest and diamond is the hardest.

Hardness of minerals can also be compared to common objects (fingernail, copper penny, nail, glass).

|  |
| --- |
| **1.Talc** (softest) **2.Gypsum←** fingernail **3.Calcite←** penny (copper) **4.Fluorite←** nail **5.Apatite←** glass **6.Orthoclase** **7.Quartz** **8.Topaz** **9.Corundum** **10.Diamond** (hardest)  |

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