CHAPTER 8

BASICS OF GEOLOGY

CHAPTER's Objectives

- To gain knowledge of basic geology
- To gain knowledge of earth's crust structure
- To study minerals and their properties
- To study rocks and rock formation
- To gain knowledge of types of rocks and rocks cycle

Geology is a branch of earth sciences that deals with the study of solid earth, the rocks that made it, its interior, and the changes (physical and chemical) that it undergoes (evolution.) overtime.

Earth is 4.5 billion years old and since its birth, it went through successive periods of progression by which it gained all the characteristics and features that have turned it into a unique environment for life. Its two special ingredients of oxygen and water have supported a diverse micro and macroscopic life on its atmosphere, surface, and interior.

The abundance of elements on earth surface such as carbon, silicon, iron, and others add another component to a flourished life on earth. Scientists agree that there is no other place in our universe that has or share earth with its uniqueness.

Earth is also a dynamic, but a stable system. Its stability arose from the equivalent interaction among its living organisms and from cycling of fluids and solids on its surface.

Along all of these years, the dynamic earth has changed a lot in all of its aspects. This change over time or evolution is a result of changes in its internal and external conditions. Life, on the other hand, is affected by these changes on earth in such a way that these changes allowed for the appearance of new features and characteristics on its structure, which contributed significantly to its diversity.

8.1 Chemical composition of solid earth

Solid earth is made up of different chemical elements not equally distributed and found with different amounts on its crust (the rocky part) and in its interior. About 99% of the crust is made up of eight elements and of their compounds. By weight, oxygen and silicon as Figure(8.1A) illustrates are the most abundant. Other elements constitute 1.4 percent only. For the whole earth, iron takes a high percentage as Figure (8.1B) shows suggesting that the earth was once in a molten state; the heavy elements of iron and nickel sank to the center leaving the light elements on top (more about earth interior structure in chapter 9)

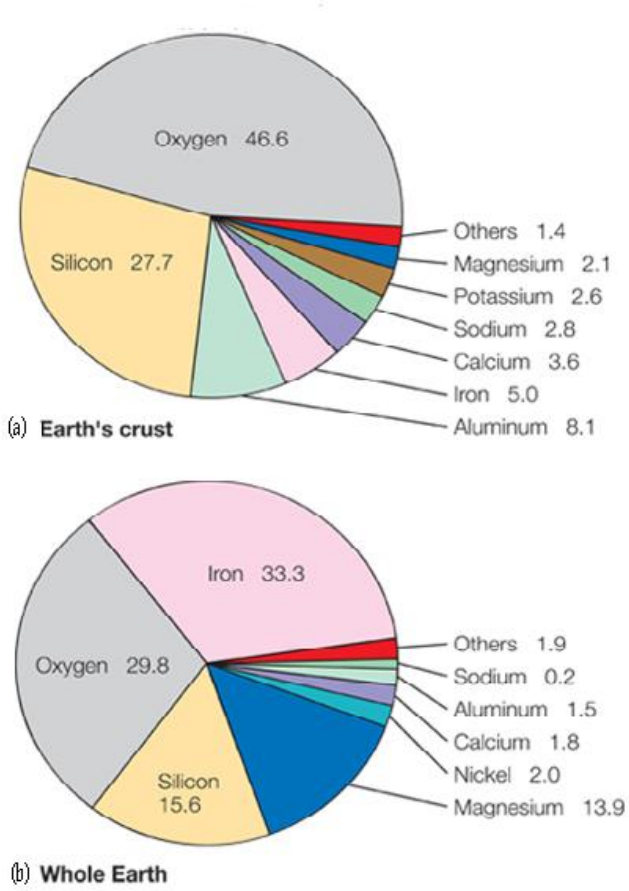


Figure (8.1): Geologic pie of elemental percentage by weight on (a) crust and (b) whole earth. Eight elements comprise about 98% of earth. Credit: B. W. Tillery, E. D. Enger, and F.C.Ross," *Integrated Science*", 3rd Ed. McGraw Hill 2007.

8.2 Minerals

In geology, a ***mineral*** is defined as an element that is found naturally, a solid element or compound, and has a crystalline shape. This definition means

- Minerals cannot be manufactured
- It is not liquid or gas
- It has a crystal structure

Crystal structure of a mineral can be made up from stacking building blocks together in an organized fashion in three dimensions like building a house from bricks or stones. The building block is called ***structural unit***; it is made up of atoms of one element or a combination of more than one atom like that of sodium chloride (table salt) shown in Figure (8.2).

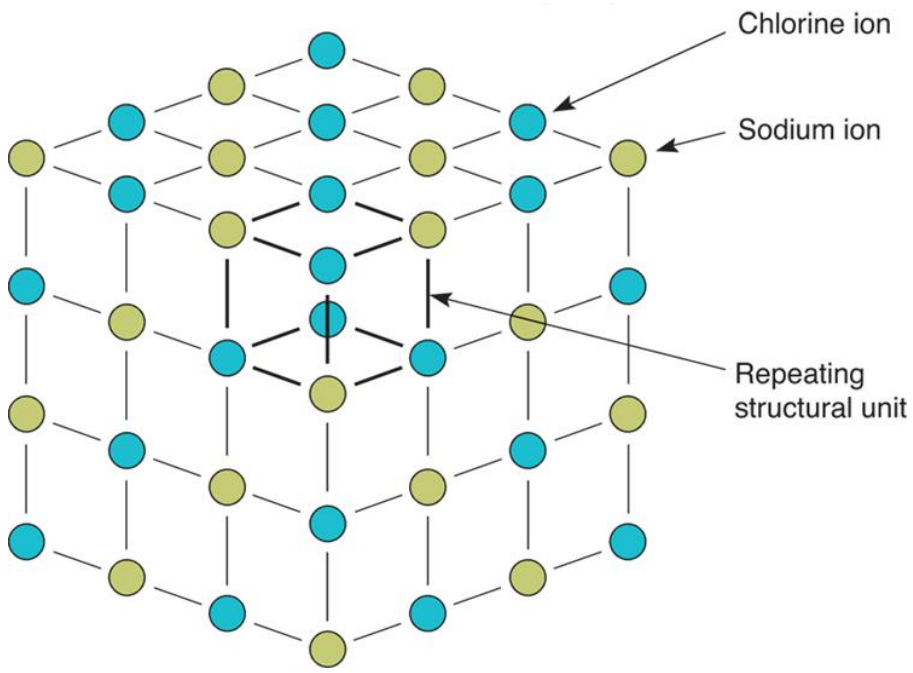


Figure (8.2): The crystal structure of sodium chloride (table salt). It builds up from a structural unit that repeats itself in an organized way in three dimension (space). Credit: B. W. Tillery, E. D. Enger, and F.C.Ross," *Integrated Science*", 3rd Ed. McGraw Hill 2007.

8.3 Mineral physical properties

Each mineral has a set of observable physical properties that depend on its internal structure. A list of these properties are described as follows

8.3.1Crystal form

Every mineral has a crystal form different from others, which can be used to identify it. The crystal form depends on the way the atoms of the mineral are arranged on the structural unit. Figure (8.3) shows the crystal structure of quartz. However, no two minerals can have same crystal form even if they have the same atoms. Graphite and diamond, for example, are chemically identical, both consist of the same element carbon but their physical appearance is different because the carbon atoms on both are differently arranged. This is illustrated in Figure (8.4a&b). Graphite and diamond are therefore show different properties.

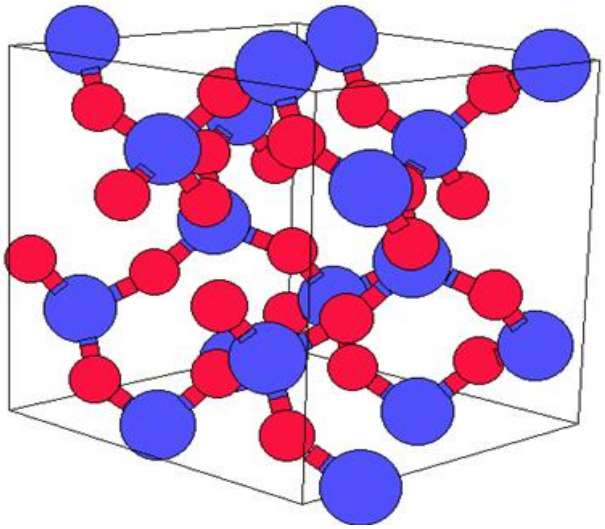
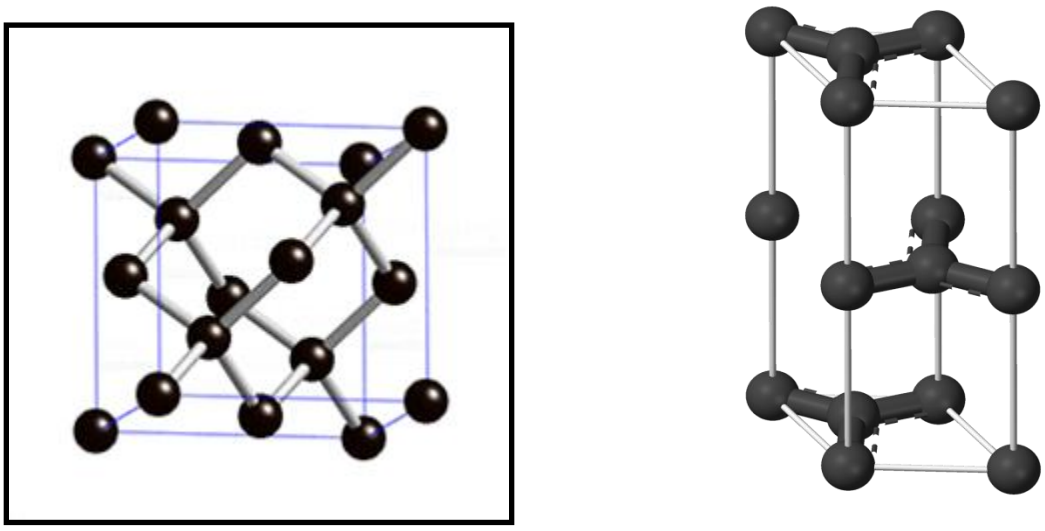


Figure (8.3): crystal structure of the mineral quartz made of atoms silicon and oxygen (SiO_2).



(a) **(b)**

Figure (8.4): (a) The structural unit of diamond and (b) the structural unit of graphite. Both diamond and graphite consists of carbon, but arranged in different pattern.

From the shape of crystal, many minerals can be identified. Figure (8.5) shows the shape of some familiar minerals.


(a)

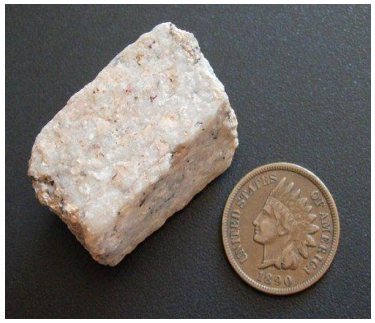

(b)


(c)


(d)


(e)


(f)


(g)


(h)

Figure (8.5): The crystal shape of (a) Quartz, (b) Graphite, (c) Andesite, (d) Basalt, (e) Topaz, (f) Gypsum Rose, (g) Feldspar (h) Pyrite.

8.3.2 Hardness

Mineral's ***hardness*** is a measure its resistance to scratching by another mineral. The degree of hardness is determined on a scale called ***Mohs scale of hardness*** ,shown below, established in 1812 by the German geologist Friedrich Mohs. On this scale, the softest mineral (Talc) is given the value of one and the hardest (diamond) is 10. To use the scale, one should scratch the surface of an unknown mineral with a mineral of known hardness. For example, if the unknown mineral offers a high resistance to scratch by Feldspar (hardness 6), but can be scratched by Quartz (hardness 7), then it's hardness lies between 6 and 7. Pyrite has a hardness 6 to 6.5.

Moh's Hardness Scale									
1	2	3	4	5	6	7	8	9	10
Talc	Gypsum	Calcite	Fluorite	Apatite	Feldspar	Quartz	Topaz	Corundum	Diamond

8.3.3 Cleavage and Fracture

The atoms in the mineral's crystal mineral are connected by bonds; some bonds are weaker than others. A mineral breaks when the weak bonds break. ***Cleavage*** describes the way a mineral breaks along its planes of weakness when it is under stress (like striking it with a hammer), much like a stack of papers when drop will spread off in individual sheets.

Minerals with different crystal structures will cleave in different ways, as Figure (8.6) shows.

Figure (8.6): Minerals of different crystal structure break at different planes. (a) Halite forms cubes when cleaves, (b) Mica tends to break in sheets, and (c) Fluorite forms octahedrons each have eight sides when cleaves

Some minerals fracture than cleave. ***Fracture*** is the tendency of a mineral to break along curved surfaces with irregular shapes as Figure(8.7) illustrates. Minerals that fracture do not have planes of weakness.

Figure (8.7): A collection of fractured minerals

8.3.4 Color

Although color is a property that identify a mineral, it is not reliable one. This is because most of the minerals are either colorless or can be found in different colors. Chemical impurities in minerals, on the other hand, may give them special colors. For example, the mineral corundum (Al_2O_3) is normally white or grayish, but impurities within it yield the well known sapphire and rubies as shown in Figure (8.8).

(a) (b)

Figure (8.8): (a) sapphire and (b) rubies are mineral corundum, which contains impurities.

8.3.5 Density

Density is the ratio of mass to volume and is a good measure of how massive a mineral is at specific size. Talc has density of 2.8 g/cm^3, Mica is 3.0 g/cm^3, pyrite is 5.0 g/cm^3, copper is 8.9 g/cm^3, silver is 10.5 g/cm^3, and gold is 19.3 g/cm^3.

8.4 Classification of minerals

Minerals are classified on the account of whether their structure contains the elements silicon and oxygen or not. ***Silicates*** are minerals that contain silicon and oxygen making up about 92% of minerals on earth's crust. The other 8% are the nonsilicates those minerals that do not contain silicon and oxygen. As Table (8.1) shows, silicates can also be divided into two main groups depending on the presence of iron and magnesium. Because of the iron ions, *ferromagnesian* are darker in color, and have greater density than the *nonferromagesians*. Figure (8.9) shows samples of both ferromagnesians and nonferromagnesians. Nonsilicates are divided into eight groups. Hydroxides is nonsilicate and it is not shown in Table (8.1).

Among the nonsilicates, the carbonates ate the most found in nature, others are used as fertilizers, sources for metals, and sources of chemical productions.

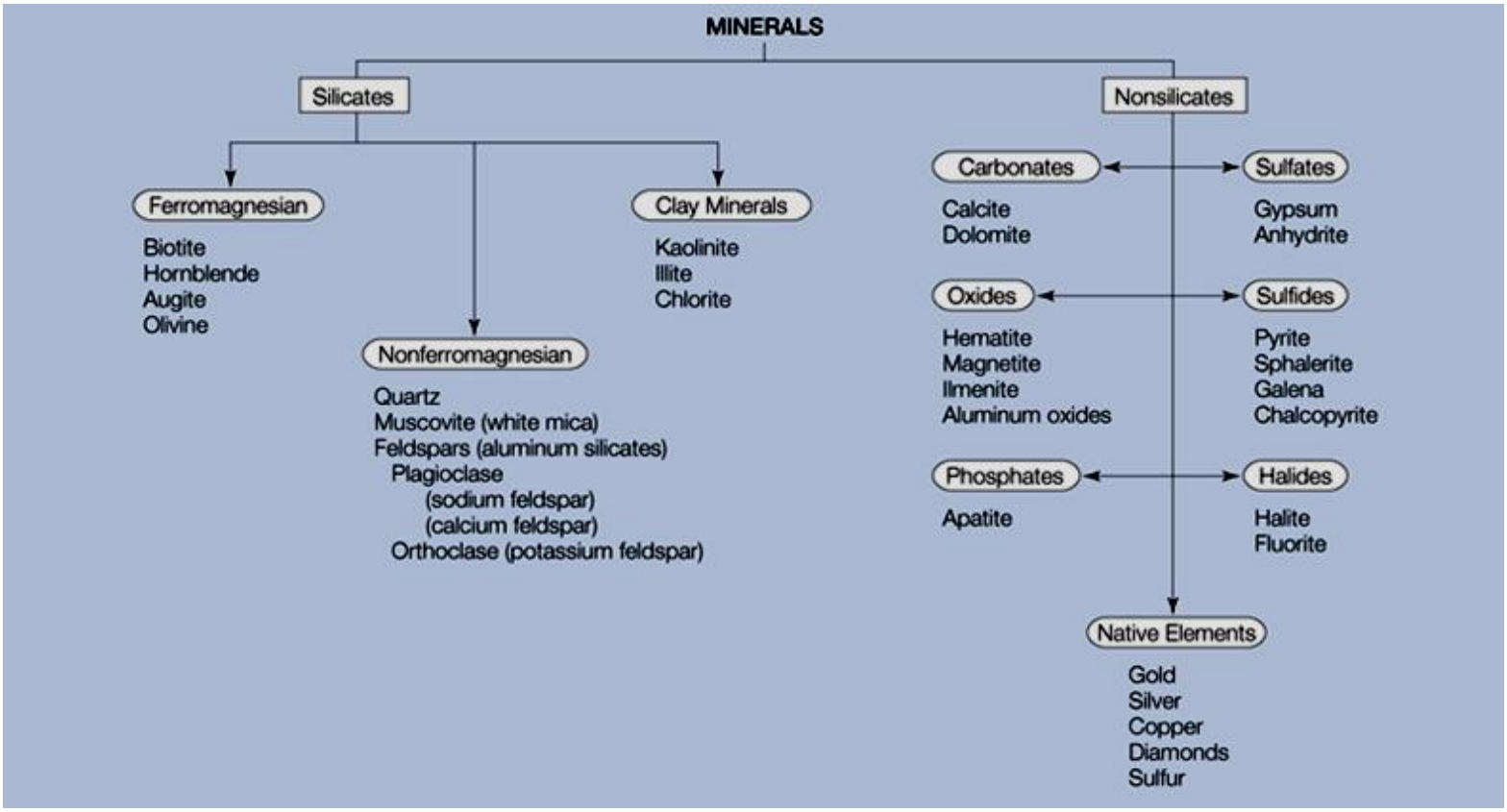


Table (8.1): Classification of minerals into silicates and nonsilicates. Credit: B. W. Tillery, E. D. Enger, and F.C.Ross," *Integrated Science*", 3rd Ed. McGraw Hill 2007.

(a) (b)

Figure (8.9): (a) ferromagnesians ar darker in colors and heavy, and (b) nonferromagnesians are light in colors and lighter in density.

8.5 Rocks

Minerals (compounds) are made from chemical combination of elements. ***Rocks***, however, are made up from physical combination of one of more of minerals plus other stuff that is not mineral like volcanic glass all exist in a compacted form (solid).

8.5.1 Classification of rocks

Depending on the way they are formed, rocks can be classified into three groups

8.5.1.1 Igneous rocks

Igneous rocks are rocks formed from previously existing rocks, which melt because of tremendous amount of heat. The process of formation of igneous rocks consists of three stages: First high temperature must be present to melt the rocks, the second stage is the formation of ***magma*** or the melted rock material (soup), and in the third stage cooling and crystallization of the magma lead into solid igneous rocks. The formation of igneous rocks takes place either under the ground or at the surface of earth. Granite and basalt shown in Figure (8.10) are two examples of igneous rocks . ***Granite*** is light colored igneous rock made up of quartz, mica, and feldspar. ***Basalt***, however, contains quartz and feldspar is dark colored and denser than granite.

(a)

(b)

Figure (8.10): (a) Granite and (b) basalt igneous rocks.

8.5.1.2 Sedimentary rocks

Over a period of millions of years, the previously existing rocks on the surface of earth underwent eroded because of the age factor. Due to a process called ***erosion*** (stage 1) parts of these rocks are separated by wind, snow, and running water. These little parts of rocks and sand that are removed are called ***sediment***. Usually, sediments are taking by water flow to the lakes and/or oceans. When the water slows down, sediments ***deposit*** (stage 2) at the bottom of lakes and oceans. Over a long period of time solid layers of these sediments are formed through sedimentation (stage 3) like a stack of papers, one paper on top of the other. The rock formed in this way is called ***sedimentary rock*** as depicted in Figure (8.11). Usually, sedimentary rocks contains the remaining of dead plants and animals buried in these layers and turned into stones. Large amounts of deposited plants in sedimentary rocks converted into carbon and provide us with coal, oil, and gas. Examples of sedimentary rocks are the sandstone, shale, coal, and limestone shown in Figure (8.12)

Figure (8.11): Sedimentary rocks are formed from stacking layers of sediments.

(a) (b) (c) (d)

Figure (8.12): (a) sandstone, (b) shale, (c) coal, and (d) limestone sedimentary rocks.

8.5.1.3 Metamorphic rocks

Metamorphic rocks are initially igneous or sedimentary rocks that have been changed by heat and pressure into different rocks. The source of heat and pressure are a result of the movement of the crust (chapter 9) and heating from magma. These effect of heat and pressure must be high enough to break the crystal structure of the preexisting rocks and then recrystallize them in a different form and not so high to melt the rocks and form igneous rocks. Examples of metamorphic rocks are, slate, schist, and gneiss as shown in Figure (8.13)

(a) (b) (c)

Figure (8.13): Examples of metamorphic rocks, (a) slate, (b) schist, and (c) gneiss.

8.6 The rock cycle

As mentioned in the introduction of this chapter, earth is a dyanamical system that changes from time to time. Changes in the interior part of earth (as we will see in chapter 9) bringes changes on the earth surface and builds mountains. Mountains exposed to environmental conditions like wind, rain, and snow erode these mountains and form sedmentay rocks. Heat from the interior of earth melt rocks into magma and form igneous rocks. Igneous and sedimentay rocks change into metamorphic rocks by pressure and heat from within due to crust movement. Metamorphic rocks melts and become magma, which in turn cool and becomes igneous rocks. This sequence of events of rocks change from one form into another is called ***rock cycle*** illustrated in Figure (8.14).

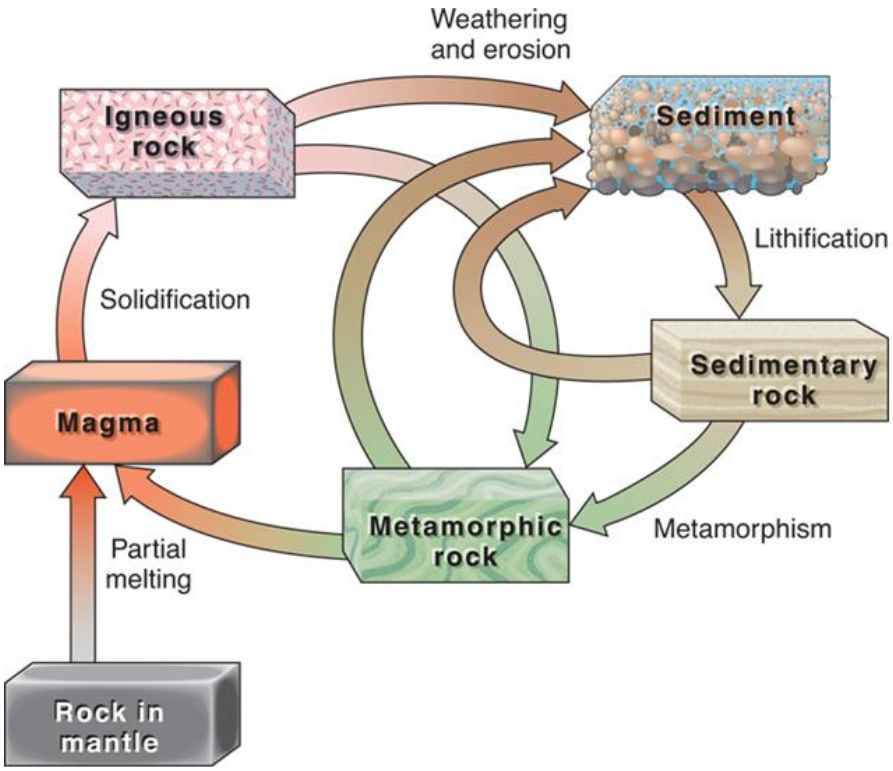


Figure (8.13): The rock cycle. Credit: B. W. Tillery, E. D. Enger, and F.C.Ross," *Integrated Science*", 3rd Ed. McGraw Hill 2007.

Summary of chapter 8

98% of the earth's upper surface, the crust, is composed eight elements, 75% of these elements are silicon and oxygen. The elements chemically combine to form a crystalline solids called *minerals*. Minerals can be identified by physical means like the type of crystal form, hardness, cleavage and fracture, color, and density. Over 90% of these minerals are composed of silicon and oxygen or *silicates*, the others are *nonsilicates*. *Ferromagnesians* are silicates mixed with iron, magnesium, and other elements. *nonferromagnesians* contain no iron and magnesium, which can be identified by light color and less density than ferromagnesians. The nonsilicates contain no silicon and oxygen are classified as carbonates, sulfates, oxides, halides, sulfides, and native elements. A rock is made up of one or more of minerals squeezed into a solid form. *Igneous rock* is a hard rock formed a s a result cooling and then recrystalization of a hot magma. *Magma* is a preexisting rock melted by the huge amount of heat within the earth interior. *Sedimentary rock* is formed from sedimentations of weathered and eroded preexisting rocks exposed to atmospheric conditions. *Metamorphic rock* is a rock formed from preexisting rocks subjected to conditions of high heat and pressure without melting. The rock cycle is a sequence of cyclic transformations of rocks from one form into another due to a change in the earth's crust.

Chapter 8 Worksheet

Part1: sentence completion

1. About 98% of the earth crust is made up of _____ elements.
2. About 75% of these elements on earth's crust are_____-, and _____.
3. A mineral is defined as an element that is found _____, a _____ element or compound, and has a_____ shape.
4. A crystal is an ordered 3D repetition of a building block called _____.
5. Both diamond and graphite are different crystal forms of _____.
6. The scale that describes a mineral hardness is called _____.
7. _____ describes the way a mineral breaks along its planes of weakness when it is under stress.
8. The tendency of a mineral to break along curved surfaces with irregular shapes is called _____.
9. The mineral that has hardness 7 is called _____.
10. To compare minerals whether they are composed of silicon and oxygen or not, geologists divided minerals into groups of _____, and _____ groups.
11. A physical combination of one or more minerals make up _____.

Part2: Multiple choices

12. Geologists divided minerals into two groups. These are
   A. Silicates and nonsilicates
   B. Chemical and mixtures
   C. Ferromagnesian and nonferromagnesian
   D. Oxygen based and non oxygen based

13. Rocks
   A. Have a definite chemical composition
   B. Are combination of one or more of minerals.
   C. Are classified by their crystalline structure
   D. Are formed when minerals chemically combine.

14. Rocks that are formed from a molten material are called
   A. Sedimentary.
   B. Igneous.
   C. Metamorphic.
   D. Magma.

15. The result of weathering and eroding rock materials form
   A. Igneous rocks.
   B. Metamorphic rocks
   C. Sedimentary rocks
   D. Magma

16. One of the following is a type of rock that has remained unchanged on Earth's surface throughout its history.
A. Igneous
B. Sedimentary
C. Metamorphic
D. None of the above

Part 3: True/False

17. Silicate minerals make up nearly a 8% of the minerals in Earth's crust.
A. True
B. False

18. Sedimentary rocks are formed from particles or dissolved materials from older rock.
A. True
B. False

19. Basalt and granite are examples of metamorphic rocks.
A. True
B. False

20. Nonferromagnesian minerals contain iron and magnesium**.**
A. True
B. False

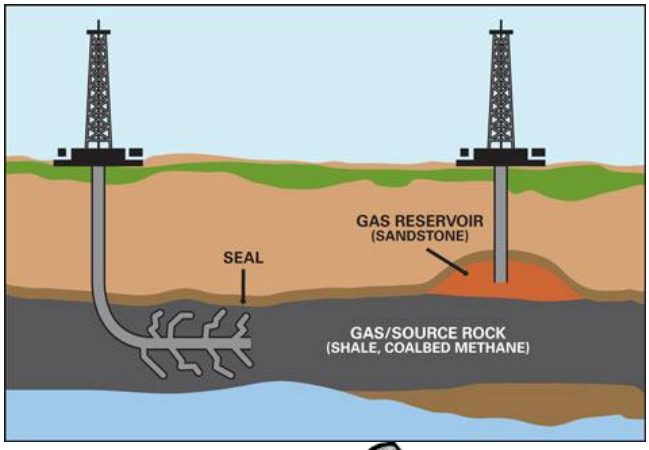
21. Rocks on earth are in a state of temporary, so that they can change overtime into another forms of rocks, this is called rocks cycle.
A. True
B. False

Part4: Exercises

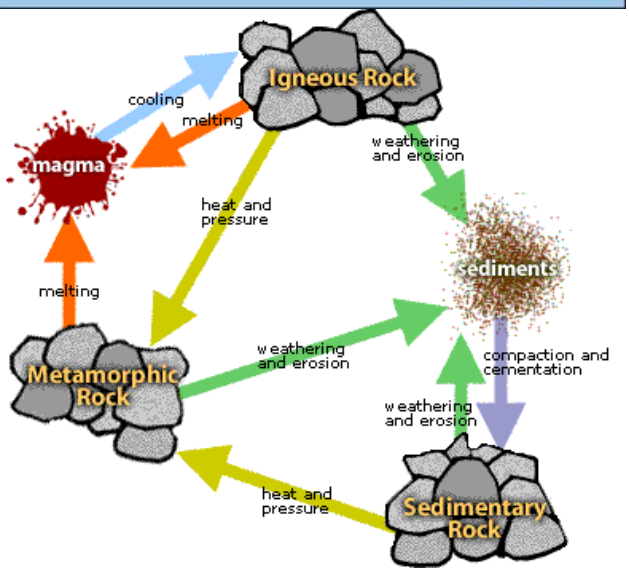
22. What is the most found mineral found on earth crust?
23. What is the most found mineral in the earth?
24. Why did iron and nickel sank deep in earth interior? Why did not silicon?
25. What is the difference between a silicate and nonsilicate mineral?
26. What makes ferromagnesians different from nonferromagnesians?
27. List two examples of igneous rocks, two of sedimentary rocks, and two of metamorphic rocks.
28. Why do you think that rocks change overtime?
29. Does the temperature increase or decrease if we go deep inside earth?
30. When water evaporates from a sample taken from red sea, what type of sediment is left behind?

Part 5: Learn from observation: In two/three lines describe what is the idea behind these photos.

31.



32.



33.