LECTURE 4

4.0 THE COMMON ROCK FORMING AND ECONOMIC MINERALS.

4.1 INTRODUCTION

Welcome to Lecture 4. From the previous lecture we were able to define a mineral. From this definition we saw that minerals can be grouped or subdivided on the basis of their two fundamental characteristics – **composition** and **crystal structure**. Recall in lecture1 that the two most common elements of the earth's crust are silicon and oxygen. It comes as no surprise therefore, that by far the largest group of minerals is the silicate group, all of which are compounds containing silicon and oxygen, and most of which contain other elements as well. In lecture 4, we shall review the classification of the basic mineral groups and give the physical properties of the common rock forming and economic minerals.

OBJECTIVES

At the end of this lecture you should be able to:

a). Define a mineral and outline the classification of minerals.

b). Describe the classification of silicate and non-silicate minerals.

c). Give examples and uses of the common rock forming minerals

d). Determine and tabulate the physical properties of various minerals.

4.2 COMMON ROCK FORMING MINERALS

By definition, a mineral is a naturally occurring crystalline material with a definite chemical composition and a definite crystal structure. Minerals by nature are classified or subdivided on the basis of their two fundamental characteristics – composition and crystal structure. Many thousands of mineral species have been recognized, but only a few of these commonly occur as rock-forming minerals. Most of the rock-forming minerals are silicates (Table 4.1). Broadly speaking, the over 3,000 known mineral species can be subdivided into **Silicate** and **Non-silicate** minerals.

Table 4.1: Classification of the Common Rock Forming Minerals

FAMILY	**SPECIES**	**STRUCTURAL CLASS**	**COMPOSITION**
Quartz	Quartz	Tectosilicate	SiO_2
Feldspar	Orthoclase	Tectosilicate	$KalSi_3O_8$
	Plagioclase	"	$NaAlSi_3O_8$-$CaAlSi2O_8$
Mica	Muscovite	Phyllosilicate	$KAl_2(AlSi_3O_{10})$-$(OH)_2$
	Biotite	"	
Amphibole	Hornblende	Inosilicate	$(NaCa)_2(MgFeAl)_5$ $(SiAl)_8O_{22}(OH)_2$
Pyroxene	Augite	Inosilicate	$Ca(MgFeAl)(AlSi)_2O_6$
Olivine	Olivine	Nesosilicate	$(Mg,Fe)_2SiO_4$
Clays	Kaolinite	Phyllosilicate	$KAl_2(AlSi_3)O_{10}(OH)_2$
	Illite	"	
	Montmorrilonite	"	
Carbonates	Calcite		$CaCO_3$
	Dolomite		$CaMg(CO_3)_2$

4.3 SILICATE MINERALS

Why are silicates the most common-rock forming minerals?

Noting from Lecture 1 that silicon and oxygen are the two most abundant elements in the earth's crust, it is no surprise therefore that the **silicate** minerals are the most common rock-forming minerals. The number of elements that form silicate minerals is comparatively few. However the great multiplicity of the silicate minerals is due to the variety of silicates that can be formed from the same elements.

4.3.1 Structure and Classification of the Silicates

Because this group of minerals is so large, it is subdivided on the basis of crystal structure, by the way in which the silicon and oxygen atoms are linked together. The silicate minerals consist essentially of silicon-oxygen tetrahedral. The fundamental unit in building of the atomic structure of the silicate minerals is the $[SiO_4]^{4-}$ unit in which the silicon atom (more strictly cation) is situated at the center of the tetrahedron whose corners are occupied by four oxygen atoms (Fig.4.1).

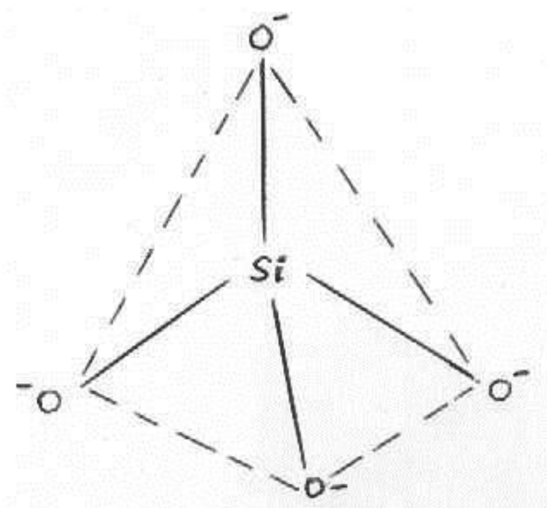

Fig. 4.1 The atomic structure of the $[SiO4]^{4-}$ unit to show how the silicon and oxygen atoms are linked.

The unit has four residual negative charges that are balanced either by appropriate cations, such as Fe^{2+}, Mg^{2+}, Na^{+}, K^{+}, Al^{3+}, hydroxyl anions and water or by the sharing of one or more oxygen atoms with other silicate units to produce stability and electrical neutrality.

The different ways in which the tetrahedral silicate building blocks are linked together, and the choice of cations to balance the negative charges, are responsible for the variety of silicate mineral species. The tetrahedral can be linked into chains, sheets or more complex frameworks. Classification of the silicates is based on the different ways in which the SiO_4 – tetrahedral occurs, either separately or linked together. The six recognized structural classes of silicate minerals are as shown in Table 4.2.

Table 4.2. Silicate mineral structural classes.

STRUCTURAL CLASS	**STRUCTURE**	**EXAMPLE**
Nesosilicate	Independent tetrahedral	Olivines
Sorosilicate	Double tetrahedral	Epidote
Cyclosilicate	Ring structure	Cordierite
Inosilicate	Chain structure	
	- Single chain	Pyroxenes
	- Double chain	Amphiboles
Phyllosilicate	Sheet structure	Micas, clays
Tectosilicate	Three-dimensional network	Quartz, feldspars

While not the most common, **quartz** is probably the best known silicate mineral. Compositionally, it is the simplest, containing only silicon and oxygen. Quartz is found in a large variety of rocks and soils. Commercially, the most common use of pure quartz is in the manufacture of glass, which also consists mostly of silicon and oxygen. Quartz-rich sand and gravel are used in very large quantities in construction.

The most abundant group of minerals in the crust is a set of chemically similar minerals known collectively as the **feldspars.** They are composed of Si, O, Al, and either Na, K, or Ca. These common minerals are made up of elements abundant in the crust. They are used extensively in the manufacture of ceramics.

Iron and Magnesium are also among the more common elements in the crust and are therefore found in many silicate minerals. **Ferromagnesian** is the general term used to describe those silicates – usually dark colored (black, brown, or green) that contain iron and /or magnesium. Examples of ferromagnesian minerals include the **Amphiboles, pyroxenes, and olivine.**

Like the feldspars, the **clays** are another group of several silicate minerals with similar physical properties, compositions, and crystal structures. Clays are sheet silicates.

Because the bonds between the sheets are relatively weak, the sheets tend to slide past each other, a characteristic that contributes to the slippery texture of many clays and related minerals. Clays are somewhat unusual among the silicates in that their structures can absorb or lose water, depending on how wet conditions are. Some clays expand as they soak up water and shrink as they dry out. A soil rich in expansive clays is a very unstable base for a building. On the other hand, clays also have important uses, especially in the making of ceramics and building materials.

4.4 NON-SILICATE MINERALS

All the non-silicate group of minerals is defined by some chemical constituent or characteristic that all members of the group have in common. Most often, the common component is the same negatively charged ion or group of atoms. The major non-silicate group of minerals, with respective examples, are listed as follows:

Carbonates – These minerals contain the CO_3^{2-} radical. Geologically the most important carbonate mineral is calcite, which is calcium carbonate, $CaCO_3$. Another common carbonate mineral is dolomite, $CaMg(CO_3)_2$.

Sulphates – These minerals contain sulfur and oxygen in the ratio of 1:4 (SO_4). The most common sulfate mineral is gypsum, $CaSO_4.2H_2O$, which is widely used for making plasters and plasterboards. It is formed by precipitation from natural waters.

Sulfides – When sulfur is present without oxygen, the resultant minerals are called sulfides. A common and well known sulfide mineral is pyrite (FeS_2). Pyrite has also been called “fools gold” because its metallic golden color often deceived early gold miners and prospectors into thinking they had struck rich. Galena, PbS, is an important ore of lead, and sphalerite ZnS, is an important source of zinc.

Oxides – Minerals containing just one or more metals combined with oxygen and lacking the other elements necessary to classify them as silicates, sulfates, carbonates, and so forth, are the oxides. The most common oxide are those of iron: magnetite (Fe_3O_4), and hematite (Fe_2O_3).

Halides – The name halide comes from halogen, meaning "salt producer". The chief minerals of this group are Halite, NaCl, Sylvite, KCl, and Fluorite, CaF_2. Halite is common table salt and occurs in large quantities as discrete layers of rock. Fluorite is found in veins and in association with calcite and dolomite deposits.

Where are the largest deposits of the mineral Fluorite located in Kenya?

NB. The largest deposits of fluorite with economic importance in Kenya occur at Kerio Valley, near Eldoret town, within the Rift Valley Province. The current mining of the deposit is done by the Kenya Fluospar company.

Native Elements – Native elements are minerals that consist of a single chemical element. Some of the most prized materials are elements such as gold, silver, and platinum, Pt. Diamond and graphite are both examples of native carbon, but here two mineral names are needed to distinguish these two very different forms of the same element.

Both Diamond and Graphite have same carbon composition and yet they show different physical properties. Why do you think so?

NB. Cross-check your answer by reading again Lecture 3, sub-section 3.3.

4.5 PHYSICAL PROPERTIES OF COMMON ROCK FORMING AND ECONOMIC MINERALS

The physical properties of the common rock forming and economic minerals are divided into metallic and non-metallic using luster as the distinguishing property. The non-metallic group of minerals will further be subdivided on the basis of those with distinctive colour and those without. Only the most definite and distinct properties of these minerals will be summarized in this topic. You are required to read and note carefully the main distinguishing features of these minerals. During your practical sessions you will be availed with various mineral specimens to identify and distinguish their main physical properties.

4.5.1 MINERALS WITH METALLIC LUSTRE

1. NATIVE GOLD - (Au)

- Yellow in colour,
- Density is very high 19.3,
- Hardness 2-3,
- No cleavage
- It is malleable.

2. NATIVE COPPER - (Cu):

- Malleable,
- Copper colour but often stained green,
- Hardness 2-3,
- Density high = 9,
- No cleavage.

3. CHALCOPYRITE - ($CuFeS_2$):

- No cleavage,
- Density high,
- Hardness 3-4,
- Colour yellow to brassy,
- Streak dark green to black,
- An ore of copper.

4. HAEMATITE - (Fe_2O_3):

- Most important ore of iron.
- May be earthy,
- No cleavage,
- Hardness 5-6
- Density high,
- Streak is red brown.

5. MAGNETITE - (Fe_3O_4)

- An ore of iron

- No cleavage
- Usually black in colour and streak
- It is magnetic
- Has high density

6. PYRITE - (FeS_2) or 'FOOL'S GOLD'

- Often a massive ore that occurs in cubic crystals with striated faces
- No cleavage
- Hardness 6-6½
- Density is high
- Colour is brass yellow or tarnished darker
- Streak is greenish black

7. GALENA - (PbS)

- Often occurs in cubic crystals,
- Has perfect cubic cleavage,
- Hardness 2½,
- Density is high,
- Colour is lead-grey,
- Streak is grey to grey-black
- It's an ore of lead.

4.5.2 MINERALS WITH NON-METALLIC LUSTRE

SECTION A:

4.5.2.1 Non Metallic Minerals with Distinctive Colour

1. MALACHITE - ($Cu_2CO_3(OH)_2$)

- Bright green in colour as well as the streak
- Often in rounded or concentric forms
- Hardness 3½ - 4
- Heavy when compact
- An ore of copper

2. AZURITE - ($Cu_3(CO_3)(OH_2)$)

- Bright blue in colour and streak
- Hardness 3½ - 4

3. GRAPHITE - (C)

- Can appear metallic
- Colour is grey to black
- Streak black, will write on paper
- Touch greasy (NB compare this property with diamond in terms of structure !)
- Hardness 1-2

4. MUSCOVITE (MICA) – (K, Al SILICATE)

- Since it is a mica, it has perfect cleavage in one direction and it cleaves into paper-thin transparent flakes
- Colourless but frequently appears silvery non-metallic.
- Hardness 2-2½
- Flakes (cleavage) are flexible

5. BIOTITE (MICA) - (K, Mg Fe, Al Silicate)

- Flexible cleavage flakes like the pages of a book
- Usually appears shinny black
- Hardness 2½ - 3

6. OLIVINE - (Mg, Fe silicate)

- No cleavage
- Hardness 6½ - 7
- Colour yellow to green
- Usually occurs in granular (in small grains) form.

SECTION B :

4.5.2.2 Non-Metallic Minerals with no Diagnostic Colour

1. ROCK SALT - (NaCl)

- Occurs in cubic crystals
- Salty taste
- Hardness 2½
- Perfect cubic cleavage
- Transparent when pure

2. CALCITE - ($CaCO_3$)

- Perfect cleavages
- Hardness 3
- Usually colourless or white
- Effervesces with dilute hydrochloric acid

3. GYPSUM - ($CaSO_4.2H_2O$)

- Hardness 2
- One good cleavage
- Usually white or colourless

4. FLOURITE - (CaF_2)

- Crystals often cubit
- Good cleavages
- Hardness 4
- Feels above average density for a non metallic mineral
- No reaction with hydrochloric acid.

5. BARITE - ($BaSO_4$)

- Good cleavages
- Hardness 2½ - 3½
- High density

6. TALC - (Mg, OH Silicate)

- Touch is greasy
- Luster is pearly
- One perfect cleavage
- Hardness 1

7. CORUNDUM - (Al_2O_3)

- Good cleavages
- Hardness 9
- Quite dense
- Used as an ABRASIVE and as a GEMSTONE e.g. ruby and sapphire

8. BAUXITE - (Hydrous Aluminium Oxide)

- Earthy masses
- No cleavage
- Hardness 1-3
- Smells of earth- clay

9. QUARTZ - (SiO_2)

- No cleavage

- Conchoidal fracture
- Hardness 7
- Can be transparent

10. PLAGIOCLASE FELDSPAR (Ca, Na, Al Silicates)

- Good cleavages
- Hardness 6-6½
- Usually white to dark grey

11. POTASSIUM FELDSPAR - (K, Al Silicate)

- Good cleavages
- Hardness 6
- Often pink colour

12. AMPHIBOLE - (Ca, Mg, Fe, Al, Na Silicates)

- Hornblende is the most common
- Two good cleavages that intercept at 60 and 120 degrees
- Commonly black.

13. PYROXENE (Ca, Fe, Mg, Al, Na, Silicates)

- Common one is AUGITE
- Two good cleavages that intercept at 90 degrees
- Hardness 5 to 6
- Usually green to black

14. GARNET (Ca, Mg, Fe, Mn, Al Silicates)

- Often in perfect 12-24 sided crystals
- No cleavages
- Hardness 6½ - 7½
- High density

Using your lecture notes and knowledge obtained from this topic, attempt to complete the physical properties of minerals tabulated in Table 3.1 in the previous chapter.

Summary

By far the most abundant minerals in the earth's crust and mantle are the silicates. They can be subdivided into groups on the basis of their crystal structures by the ways in which the silicon and oxygen atoms are arranged. The main building block of silicates is the $(SiO_4)^{4-}$ tetrahedron, and the linking of tetrahedral at the molecular level results in different internal mineral atomic structures; micas, for example, have a sheet-like structure. The non-silicate minerals are generally grouped on the basis of common chemical characteristics.

The common rock forming and economic minerals are divided into metallic and non-metallic using **luster**. Then the non-metallic group is further divided into those with distinctive colour and those without.

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