Geology

Is the science of studying the earth in terms of origin, components, form, history and processes affecting them in the past and present. The term Geology, a Greek word, consists of two parts: the first *geo* means the earth, and the second the *logos* means science.

-The importance of geology:

There's three main areas of geology which are important to people:

1- **Natural Resources** :

Includes minerals, ground water, fossil fuels, but also the materials we use in construction like gravel, aggregates and stone. Geology helps us find and use the resources, and in some manage and dispose of waste.

2- **Natural Hazards :**

Includes volcanoes, geysers, earthquakes and landslips and how to mitigate the risks of these .

3- **Engineering :**

Is about how geology effects the things we build, from houses and tower blocks to bridges or tunnels.

-Branches of geology:

1- Physical geology :

It is the study of the process an agents which brings about the changes on the earth .

2- Mineralolgy :

It is the study of the minerals .

3- Petrology :

It is the study of the composition, origin, occurrence and types of the rocks .

4- Geomorphology :

The study of the origin of landforms and their modification by dynamic processes.

5- Ocianography:

Study of the ocean and their basin .

6- Chrystallography :

The study of crystalline solids and the principles that govern their growth, external shape, and internal structure .

7- Geophysics :

This branch of geology deals with the application of principle of physics to the study of earth.

8- Geochemistry :

It concerned with composition of earth materials and the chemical changes that occur within the earth and on its surface.

-Relationship between geology and other Sciences:

1- With chemistry : Represented in geochemistry , chemistry of minerals and rocks , and hydrogeochemistry .

2- With physics : Represented in crystallography , geophysics , structural geology and optical minerals .

3- With biology : Represented in Stratigraphy and Paleontology .

4- With mathematics and statistics : Represented in quantitative interpretation of geological phenomena and representation of data in diagrams and graphs.

5- With geographic : Represented in geomorphology and understanding erosion, distribution of continents and oceans, formation of mountains, valleys and other terrestrial features.

6- With old climate : Represented in studying sediments in ancient geological times and the relation of the influential climate in those sediments at that time.

7- With astronomy : Represented in the direct relationship of the earth with the rest of the planets of the solar system, through the study of meteorites, for example, in order to understand the origin of the earth and its relationship to the universe.

8- With agricultural sciences : Represented in soil science and natural mineralogy .

9- With engineering sciences : Represented in engineering geology and identification of quarries for building materials and the choice of construction sites and identify the foundations and sites of dams and reservoirs.

10- With environment : Represented in environmental geology and Environmental pollution .

-CONSTRUCTION OF THE EARTH:

The earth is a ball with a heterogeneous structure and surrounded by a number of covers. According to many scientists, these can be defined as follows:

1-The inner cover (Barisphere) : includes the interior of the earth in the depths.

2-The rock cover (Lithosphere) : Covers the barisphere and formed the crust.

3-Water cover (Hydrosphere) : an intermittent cover from salt and fresh water and snow on the surface of the earth, including oceans, seas, rivers, bays, lakes, marshes, streams and groundwater. Water covers nearly two-thirds of the earth.

4-Gaseous cover (Atmosphere): consists of a mixture of gases and vapors that encapsulate the earth. Oxygen is 21%, nitrogen is 78% and the remaining 1% is other gases such as carbon dioxide, inactive gases (neon, xenon, crepton, etc.). The higher ratios of nitrogen and oxygen are in the need for living organisms, especially human beings.

5-Life cover (Biosphere): Includes organisms living in the atmosphere, water, and on the earth's surface, ie in the atmosphere, hydrosphere and lithosphere. The study of organisms that play important roles in geological processes, such as bacteria that have a role in the organic weathering of rocks as well as in organic sedimentation.

-Earth’s Interior :

The temperature increases towards earth's center where it may exceed 6700 C°. Heat from earth's interior is the major source of energy for the movement of earth's outer shell. The center of the earth lies at a depth of 6371 km. , and the deepest hole we have ever drilled into the Earth is only 9.6 km. There for what we know about Earth’s interior comes from indirect avenues of investigation. So how do we know what it’s like?

Every time there is an earthquake, waves of energy (called seismic waves) penetrate earth's interior. Seismic (energy) waves travel through the earth some energy bounces off harder layers called *reflection* . some energy travels through but gets bent, changing the direction the wave is traveling called *refraction* . some energy is absorbed as it encounters called *attenuation* .

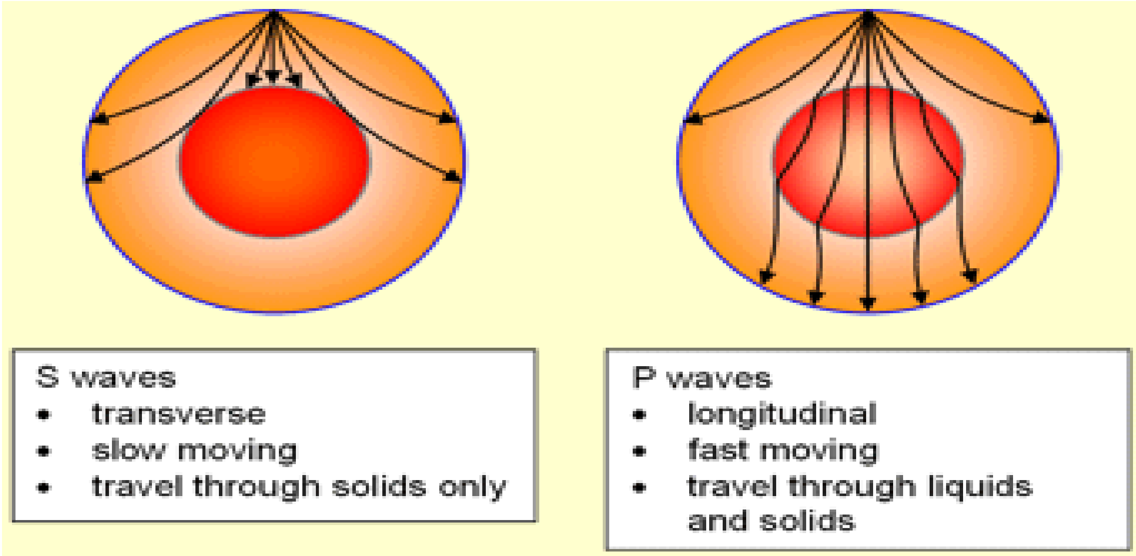
There are two main types of seismic waves :

1- **Surface Waves** : Travel slowly along Earth’s surface usually most destructive .

2- **Body Waves** : Travel more quickly through Earth’s layers . Include two types :

a- Primary wave (P Waves) : Fastest wave **,** longitudinal compression waves and travel through both solids and liquids .

b- Secondary waves (S Waves) : Slower than P waves, but faster than surface waves , Travel side to side (like a snake) , and can only travel through solids .



Wave paths are influenced by density, temperature, and the angles at which they strike boundaries as they travel through and around the Earth .

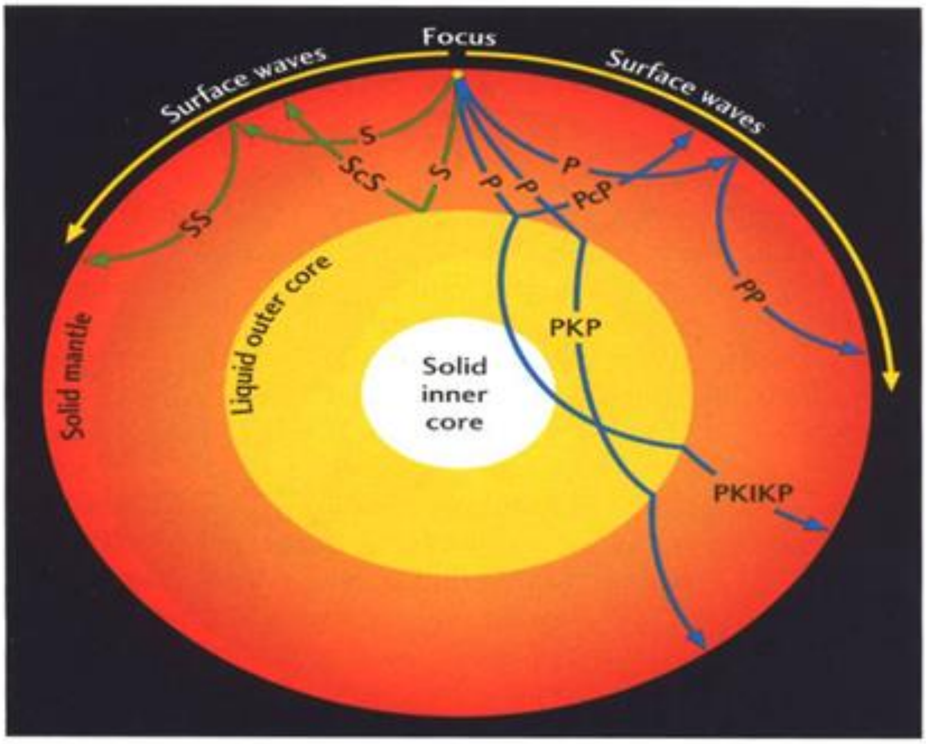


Figure P and S waves radiate from an earthquake focus in all directions. This diagram shows the simple labeling scheme seismologists use to describe the various paths the waves take. PcP and ScS are compressional and shear waves that bounce off the core. PP and SS waves are internally reflected from Earth's surface. A PKP wave is transmitted through the liquid outer core, and a PKIKP wave traverses the solid inner core. Surface waves propagate along Earth's outer surface, like waves on the surface of a pond.

The data of seismic waves analyzed and used to work out the structure of earth' interior. Scientists have determined that earth' interior is divided into four major layers.

A- Inner core.

B- Outer core.

C- Mantle.

D- Crust.

A- Inner core:

At earth's center is the inner core. It is solid and sphere , It consists of iron and nickel metals, and extends in depth between 6371-5155 km, and having a diameter of 2432 kilometers.

B- Outer core:

Surrounding the inner core is the outer core, a fluid, metallic layer. It is made of ferrous metal and nickel with sulfur, and extends in depth between 5155-2900 km , and some 2260 kilometers thick .

C- Mantle:

Beyond the outer core is the mantle, a solid, rocky layer having a thickness of about 2800 kilometers, and extends in depth between 2900-100 km . Over 82% of earth's volume is contained within the mantle.

The rock that makes up the mantle is composed of silicate minerals that are rich in iron and magnesium.

The mantle is divided into three sections **:**

1- **Lower Mantle :**

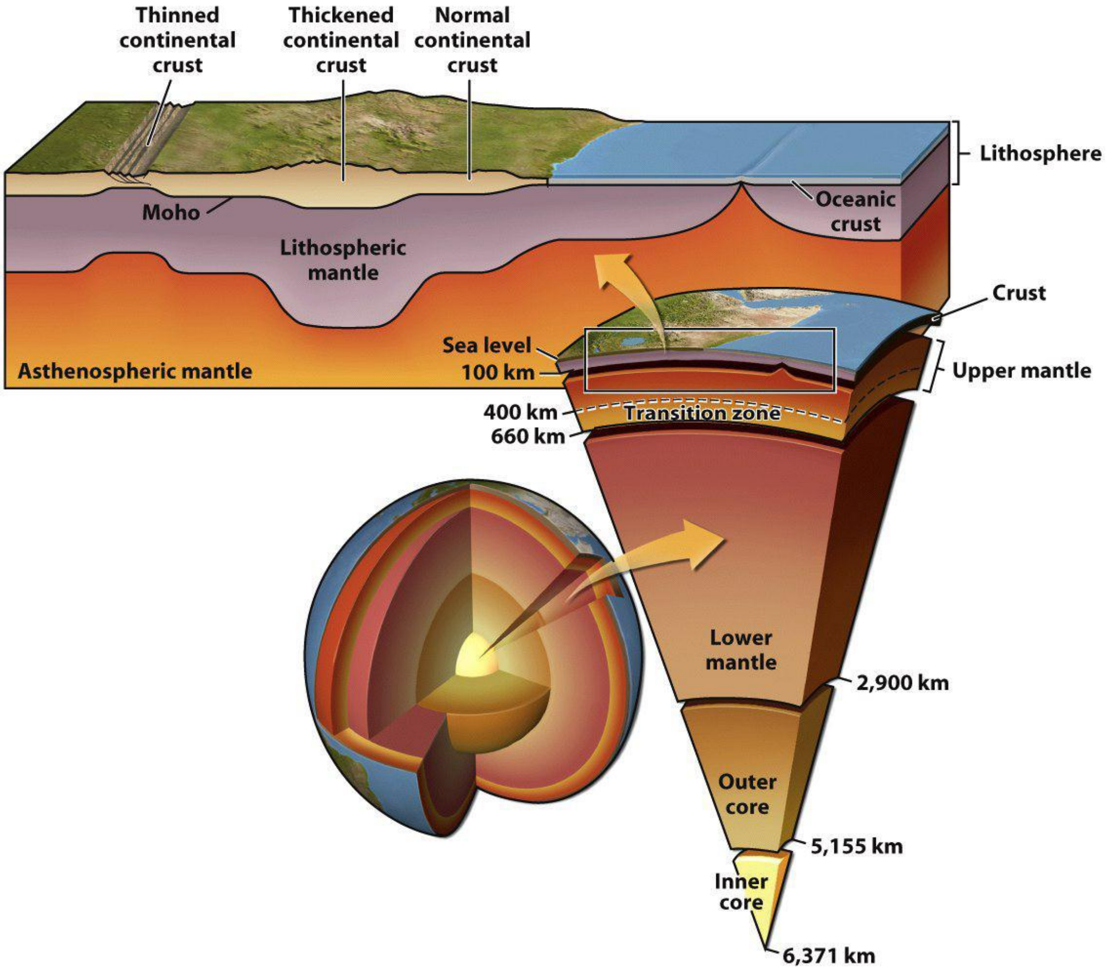
Extending between a depth of 2900 to 1000 km, meaning to discontinuity core-mantle separation between the core-mantle. It is mainly composed of iron and magnesium silicate.

2- Transition Zone :

It is located between the Lower Mantle and the Upper Mantle between 1000 and 400 km.

3- Upper Mantle :

It lies directly under the crust and extends to a depth of 400 km below the surface of the earth.



D. Crust:

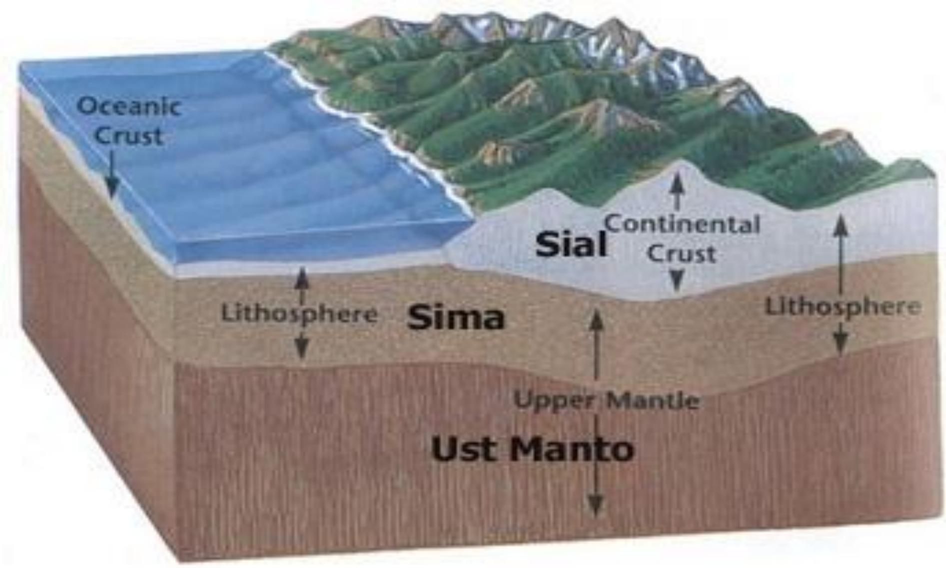
The outermost layer is the **crust** . It extends from the surface to the (Moho Discontinuity defined by seismic discontinuity indicating significant *change in composition*) , which separates the Mantle and the crust, at a varying depth at rates of 30 to 50 km below the continental areas and about 10 to 12 km below the oceanic regions, so the crust is divided into two types: **continental and Oceanic.**

The **asthenosphere** is a soft layer of the upper mantle on which pieces of the lithosphere move (asthenes is Greek for soft or weak) , material is like warm tar and can flow slowly . The rigid crust and lithosphere float on the hot, plastic material of the asthenosphere.

-Components of the crust:

The crust is generally an outer thin layer that surrounds the earth as a cover of sedimentary material with other layers that have been submerged. The first layer is a light layer to extend about 25 km, composed of granitic rocks or the like, called **Sial**, relative to the components of rocks containing a high proportion of Silicon Si and aluminum Al . Below it is a darker layer, consisting of igneous basic rocks, with a thickness of about 20 km, called **Sima**, Relative to the composition of its rocks containing high proportion of silicon Si and magnesium Mg , This layer ends at (Moho Discontinuity), which separates the Mantle and the crust .

The continental crust that forms the continents (land) contains both species Sial (with a thickness of 25 km) and Sima (20 km thickness) , While there is no sial layer in the oceanic crust and there is only a sima layer (at a thickness of about 5 km). As shown in the fig .



The outer part of the earth consists of very high rates (95%) from igneous and metamorphic rocks with a thin cover from sedimentary rocks (5%) (The clay rocks forms (4%) , the sandstone is (0.75%) and the rest is limestone (0.25%)) .

-Chemical constituents of the earth's crust:

The earth's crust consists of eight major chemical elements: oxygen, silicon, aluminum, iron, calcium, magnesium, sodium and potassium. Accounting for approximately 98.5% weight . While the remaining elements (less concentrated) are secondary and constitute a total of 1.5% weight. Because of the high Electronegativity properties of oxygen as well as the high proportion of the components of the earth's crust, so oxygen is the most negative element tendency to union with the rest of the positive elements mentioned to form oxides. On this basis, geologists prefer to write the components of minerals and rocks as oxides when analyzed chemically. So writing the components of the earth's crust as oxides will give a clearer picture, especially if we know that the oxides represent the minerals building unit as will be explained later. The following table shows the main percentages of oxides forming the crust:

Oxide	wt%	Oxide	wt%
SiO_2	59.07	H_2O	1.30
Al_2O_3	15.22	CO_2	0.35
Fe_2O_3	3.10	TiO_2	1.03
FeO	3.71	P_2O_5	0.30
MgO	3.45	MnO	0.11
CaO	5.10	Others	0.44
Na_2O	3.71		
K_2O	3.11	Total	100

Secondary elements (others) Which constitute a total of 1.5% weight are divided into four groups based on the limits of specific concentrations as follows:

1- Between 1% to 0.1% (such as Ba,Cr,Sr,Cl,F,S).

2- Between 0.1% to 0.01% (such as Cu,Co,Pb,Ni,Ag,Th).

3- Between 0.01% to 0.001% (such as As,Mo,U,B).

4- Between 1 to 10 part per million (ppm) (such as Bi,I).

CRYSTALLOGRAPHY

The science that examines the arrangement of atoms in solids. "crystallography" derives from the Greek words crystallon "cold drop, frozen drop"

Crystal: is a solid body surrounded by flat surfaces with regular geometrical shapes that vary according to the nature of each mineral. The crystal represents a reflection of the internal atomic arrangement of the mineral.

-Crystals properties: Crystal has the basic elements that must be available and must be understood and has been neutralized as follows:

1-Crystal faces: Are the surfaces that define the shape of the crystal which is mostly flat, and rarely to be convex or concave. These surfaces Indicate a regular atomic arrangement engineering firm, which consists on the basis of the crystal material. (Figure.1).

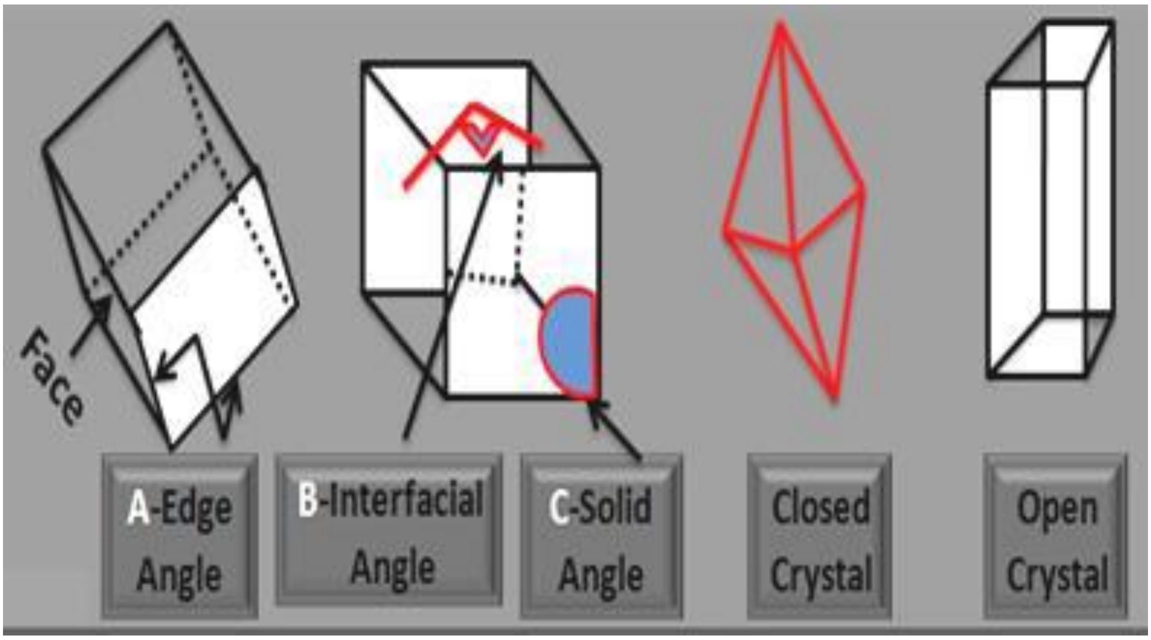


Figure.1: Crystal faces, crystal angles and crystal form of crystals properties

2- Crystal angles: There are three types of angles as follows :

a-Edge angle: It is an angle between two neighbor faces.

b- Interfacial angle: It is an angle between two faces; it can be measured by two perpendicular columns on neighbor and opposite faces.

c- Solid angle: It is an angle between three neighbor faces.

3- Crystal form:

They are similar surface of the crystal in which consists of each type of face or two faces and at least one related to the crystal axes. The crystal can be formed of one shape of faces named (simple form) or many shapes named (compound form).

4- Crystallographic Axes :

Imaginary lines intersect within the crystal at its center and extend to the middle of the different crystalline facets , these are refer to the locations of the crystal faces, where each face cuts one or more axes at a certain distance from the center , which is normally three axes: a. b. c. (Figure.2).

- **Axis a:** It is the line that extends vertically in a reading from the crystal examined.
- **Axis b:** is the axis that runs parallel to the development of reading for those who examine the crystal.
- **Axis c:** Are the vertical axes, which are more axes mostly uniform.

The three crystalline axes consist of crystalline angles called (α, β, γ) as follows :

c ∧ b = α **c ∧ a = β** **a ∧ b = γ**

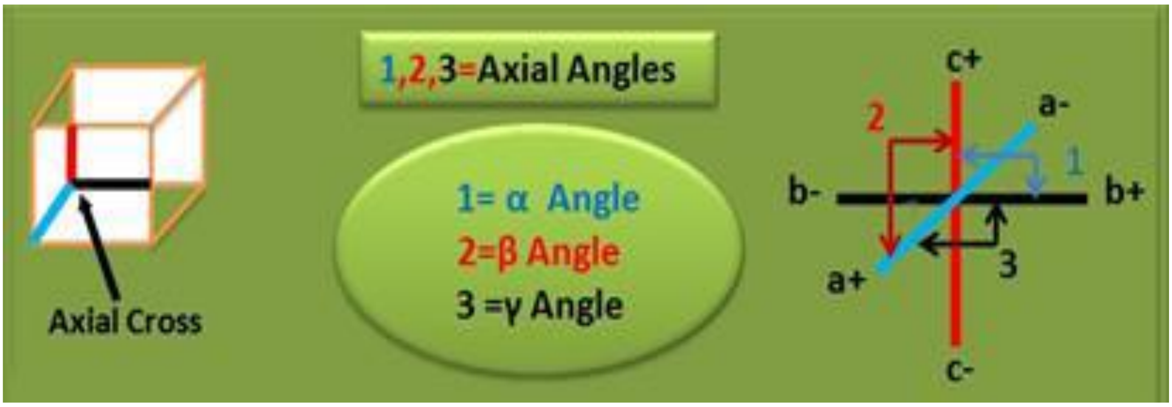


Figure.2: Crystallographic and axial angles.

5- Crystal symmetry:

It is a phenomenon of the formation of a regular crystalline form depending on the arrangement of the atoms and ions forming the material in accordance with the coordination of certain natural **.** The symmetry appears by repeating the face, edge or solid angle when the crystal rotates a full cycle (360°) around the axis , or the crystal can be divided into similar halves.

- Elements of symmetry:

Are signs of a fake attributed to the crystal symmetry, a point or line or level, single or combined, as follows:

a- Plane of symmetry.

b- Axis of symmetry.

c- Center of symmetry.

a- Plane of symmetry:

It is the plane at which the crystal is divided into two equal halves, each half a mirror image of the other. (Figure.3).

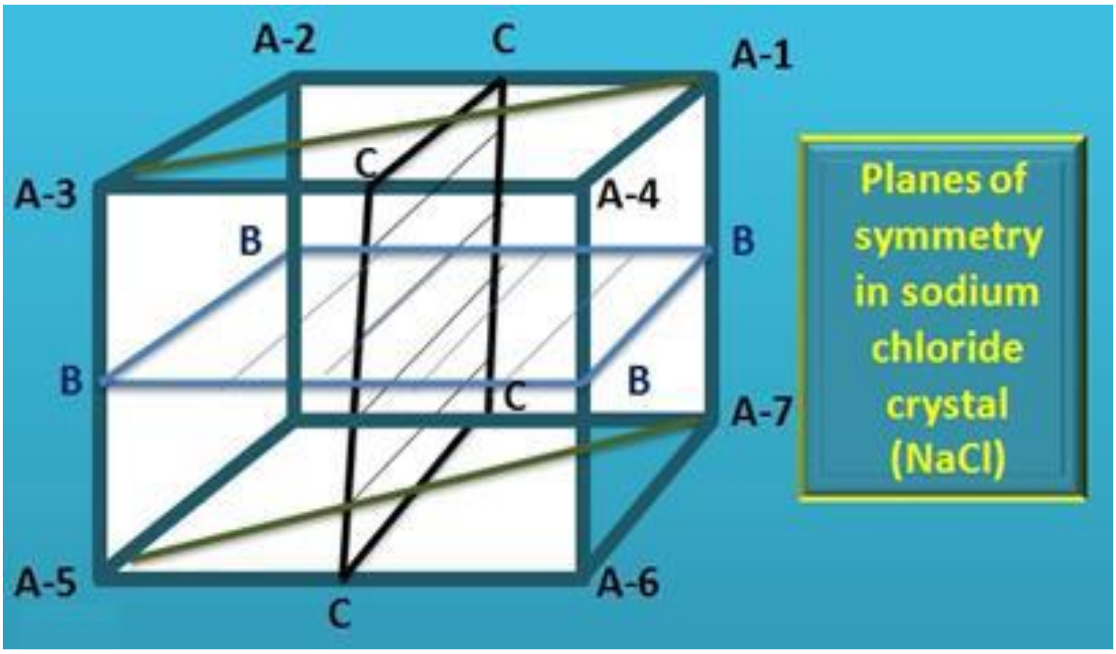


Figure.3: Plane of symmetry into sodium chloride.

b- Axis of symmetry:

It is an imaginary line passes through crystal center. If the crystal is rotated around that line (360°), face, edge and any line of crystal repeating its self twice or more. (Figure.4).

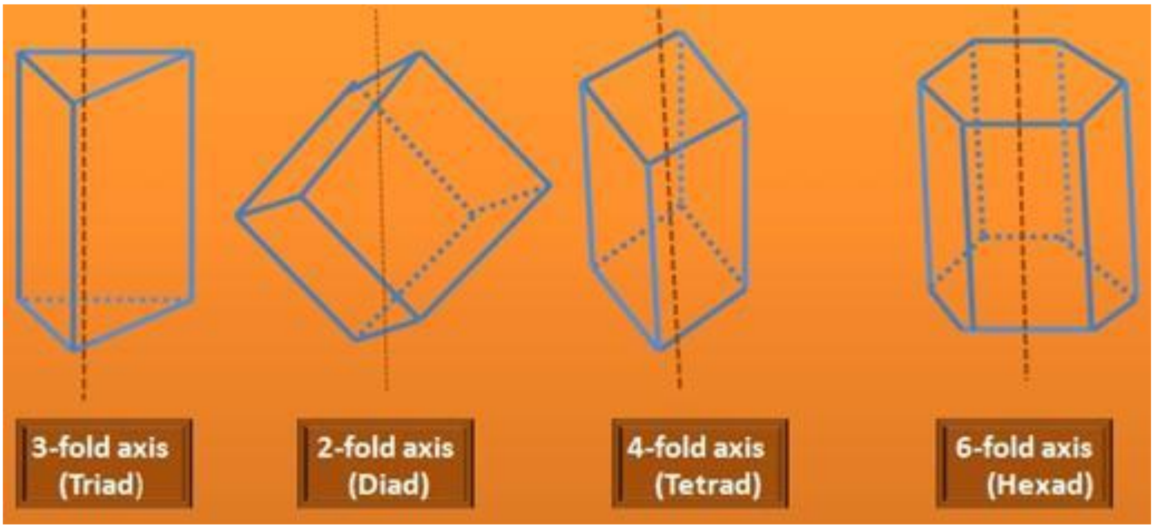


Figure.4: Types of axis of symmetry.

c- Center of symmetry:

It is a central imaginary point into crystal, that's where the distance of face, edge, and angle in certain side are equal to the other in opposite side from the center.

- crystal Systems:

Depend on the axis lengths of crystal and the axial angles between (α, β, γ). the crystal systems divided into six system.

1-Cubic or Isometric system.

2-Tetragonal system.

3- Orthorhombic system.

4- Hexagonal system.

5 - Monoclinic system.

6-Triclinic system.

1- Cubic system:

A- Crystallographic axis:

1- Three axes.

2- Equal axes. (a = b = c)

3- Perpendicular axes. (α = β = γ = 90˚)

B- Elements of symmetry:

1- Axis of Symmetry=13 axis (3^4 , 4^3 , 6^2) , (3 Tetrad , 4 Triad , 6 Diad)

1- Planes of symmetry= 9

3- Center of symmetry= present. (Figure.5).

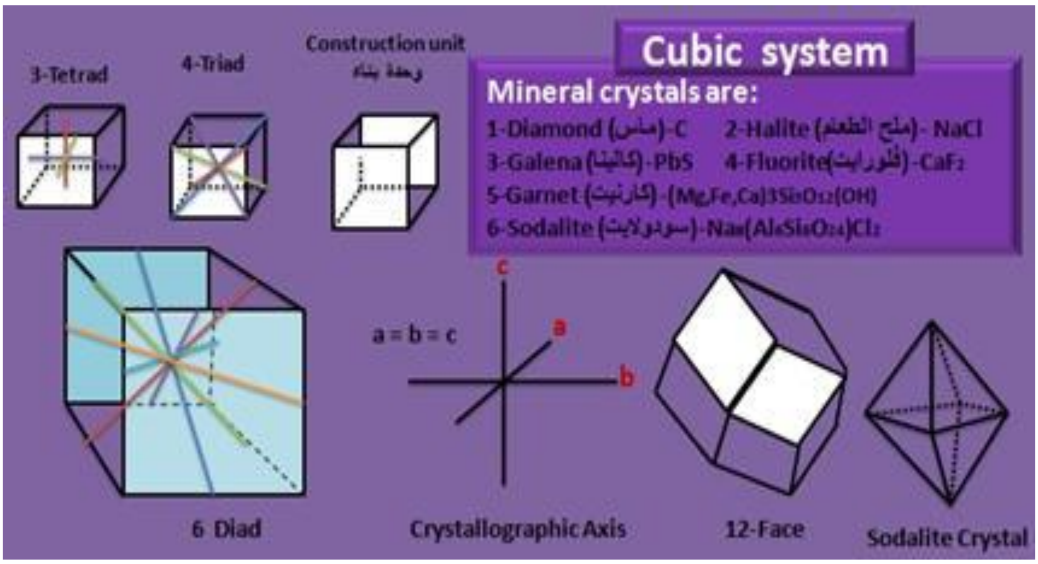


Figure.5: Element of symmetry of cubic system.

2- Tetragonal System:

A- Crystallographic Axes:

1-Three axes (two are equal, while the third is longer or shorter and vertical on the two equal axes). $a = b \neq c$.

2- Perpendicular axes. ($\alpha = \beta = \gamma = 90^{\circ}$)

B- Elements of Symmetry:

1- Axis of symmetry= 5 Axis , (4^2 , 1^4) , (1Tetrad , 4 Diad).

2- Planes of symmetry= 5

3- Center of symmetry= present. (Figure.6).

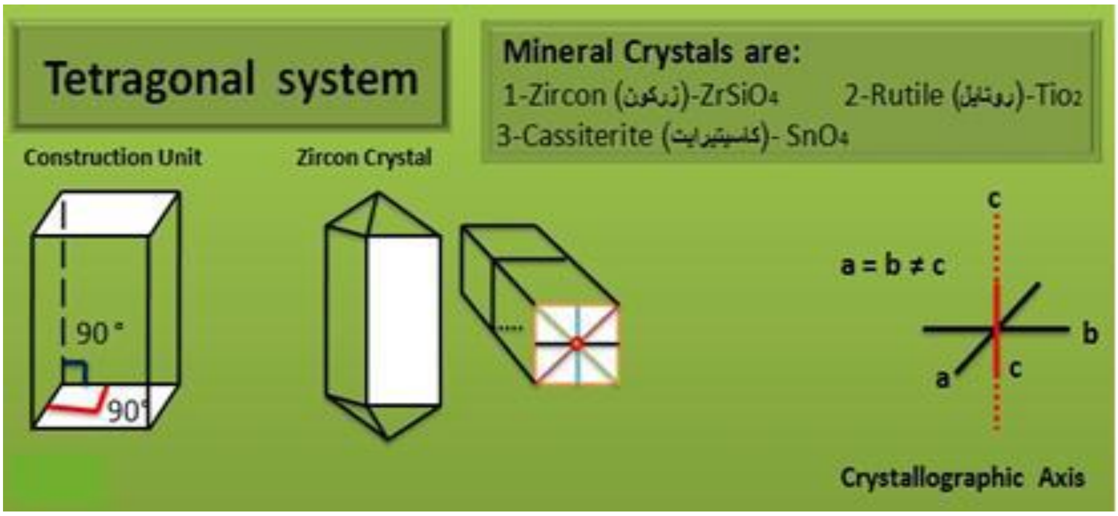


Figure. 6: Elements of symmetry of tetragonal system.

3- Orthorhombic system:

A- Crystallographic axes:

1-Three different length axes. $a \neq b \neq c$.

2-The axes are perpendicular on each other. ($\alpha = \beta = \gamma = 90^{\circ}$) .

b-Elements of symmetry:

1- Axes of symmetry = 3 (Diad).

2- Planes of symmetry = 3

3- Center of symmetry = present. (Figure.7).

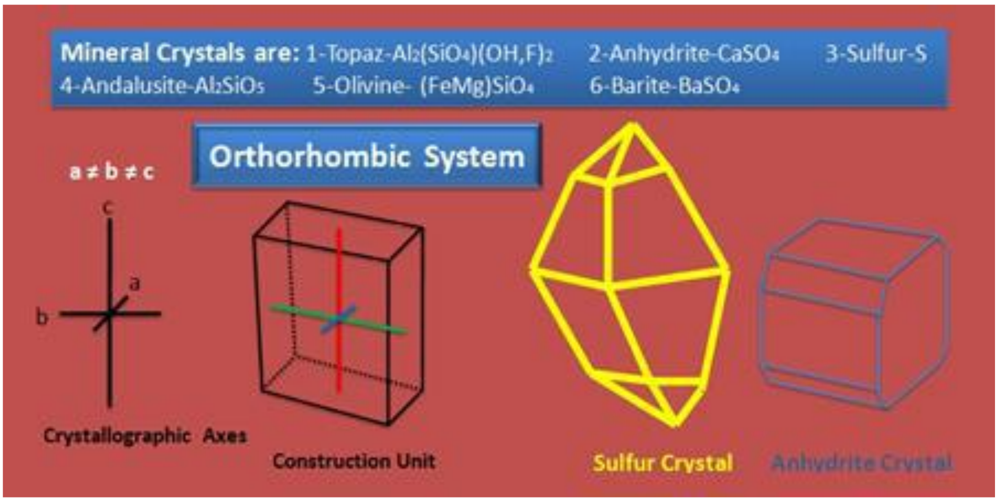


Figure.7: Crystallographic axes and elements of symmetry of orthorhombic system.

4- Hexagonal system:

A- Crystallographic axes:

Four axes (Three are equal; The angle between each two axis is (120°). Fourth axis is longer or shorter and perpendicular on the plane of three equal axes).

$a_1 = a_2 = a_3 \neq c$. $c \perp (a_1 , a_2 , a_3)$.

$a_1 \wedge a_2 = 120^\circ$ $a_2 \wedge a_3 = 120^\circ$ $a_3 \wedge a_1 = 120^\circ$

B- Elements of symmetry:

1- Axes of symmetry= 7axes (1. Hexad , 6. Diad).

2- Plane of symmetry= 7

3- Center of symmetry= present. (Figure.8).

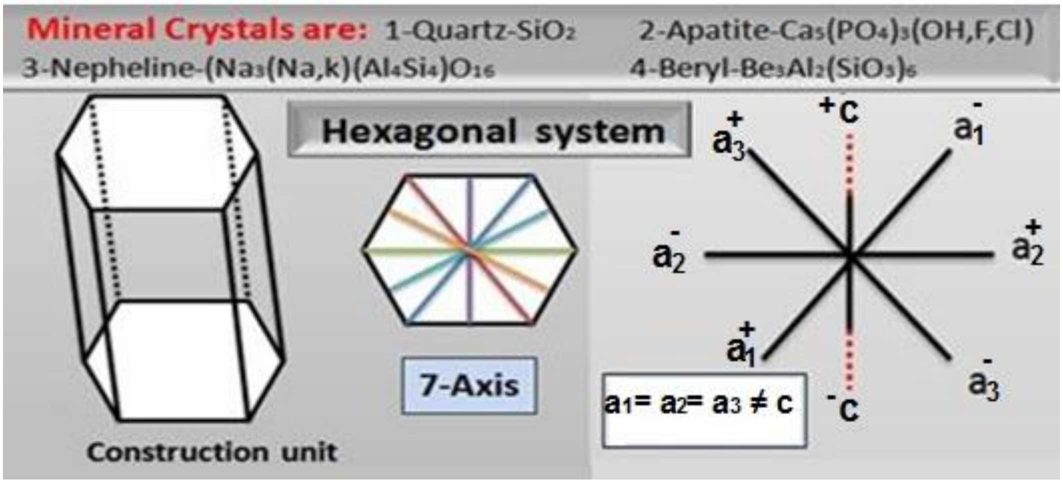


Figure.8: Elements of symmetry of hexagonal system.

5- Monoclinic system:

A- Crystallographic axes:

1- Three unequal axes. ($a \neq b \neq c$) .

2- Two axes intersects (a and c) at inclined angle (β) .

Beta angle sandwiched between a and c axes. Differ in the value of different metal crystals, which is less than 90 degrees in the lateral direction, and more than 90 degrees in the direction of the medial.

$\alpha = \gamma = 90^o$, $\beta > 90^o$.

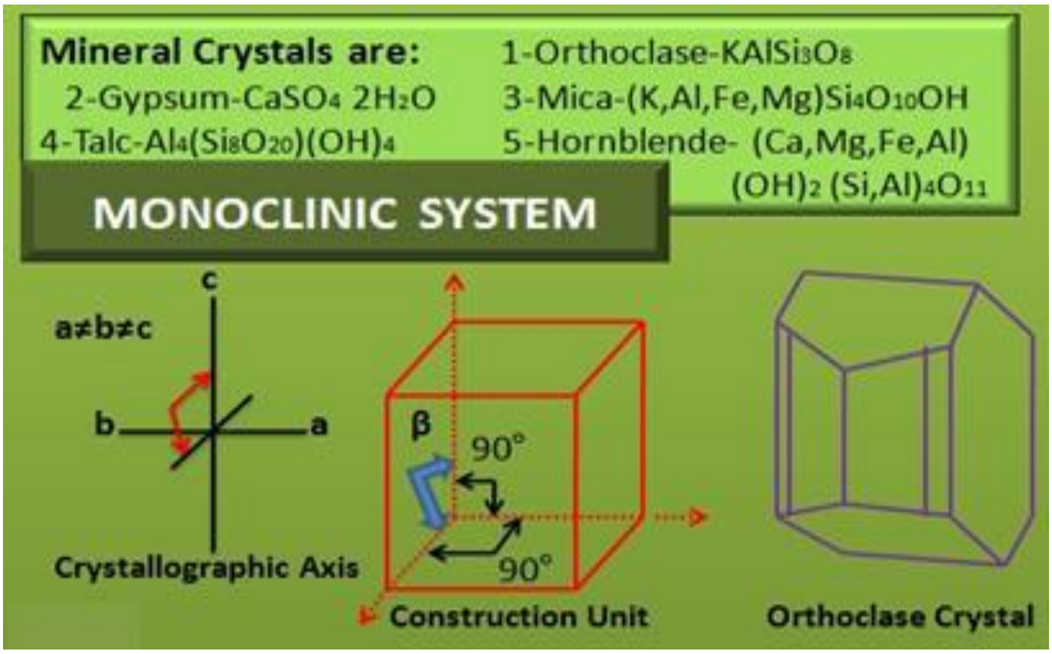
3- Third axis (b) is perpendicular on the plane of (a and c).

B- Elements of Symmetry:

1- Axis of symmetry = 1 (Diad) conformable with (b) Axis.

2- Planes of Symmetry = 1 pass by (a and c axis).

3- Center of symmetry = present. (Figure.9).



Figurer.9: Crystallographic axes and elements of symmetry of monoclinic system.

6- Triclinic system:

A- Crystallographic axes:

1- Three unequal axes. $a \neq b \neq c$.

2- Un-perpendicular axes. $\alpha \neq \beta \neq \gamma \neq 90^{\circ}$.

B- Elements of Symmetry:

1- Axes of symmetry = absent.

2- Planes of symmetry = absent.

3- Center of symmetry = present. (Figure.10).

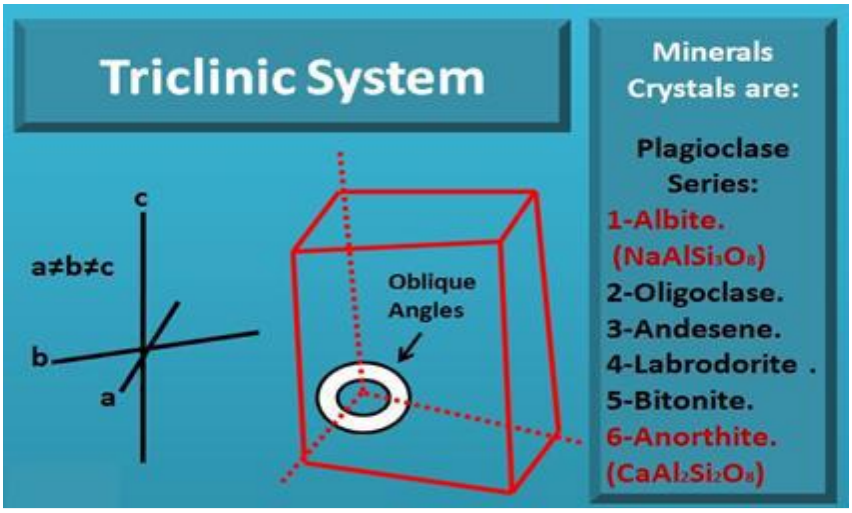


Figure.10: Crystallographic axes and elements of symmetry of triclinic system.

MINERALOGY

Mineralogy is the science of studying the minerals . A mineral is a naturally occurring substance, representable by a chemical formula, that is solid and inorganic, and has a crystal structure and physical properties.

Characteristics that all minerals share :

1. Naturally occurring : means that the substance must occur in nature, it cannot be created or manufactured by people.
2. Inorganic : means that a mineral cannot come from something that was once living.
3. Solid : has a definite volume and shape, its particles are tightly packed together and cannot move easily.
4. Crystal structure : means the particles that make a mineral line up in a pattern that repeats over and over again, this pattern creates a crystal .
5. Definite chemical composition : means that a mineral always contains certain elements in definite, or exact, proportions .

Some minerals are found in an amorphous form such as Opal and Flint, and There are crystalline minerals such as Quartz.

There are over (5,300) known mineral species; over (5,070) of these have been approved by the International Mineralogical Association (IMA). The silicate minerals compose over (90%) of the Earth's crust. The diversity and abundance of mineral species is controlled by the Earth's chemistry. Silicon and oxygen constitute approximately (75%) of the Earth's crust, which translates directly into the predominance of silicate minerals.

Minerals properties :

Minerals are distinguished by various chemical and physical properties. Differences in chemical composition and crystal structure distinguish various species, and these properties in turn are influenced by the mineral's geological environment of formation. Changes in the temperature, pressure, or bulk composition of a rock mass cause changes in its minerals.

A- Chemical properties :

Some minerals consist of one element, this type either be metallic such as gold (Au) , silver (Ag) and copper (Cu), or non-metallic such as graphite (C) and sulfur (S). Some of the other minerals component of union two elements such as quartz (SiO_2) and magnetite (Fe_3O_4) . While most of minerals in nature component of union three elements or more such as calcite ($CaCO_3$) and olivine $(Mg,Fe)_2SiO_4$.

B- Physical properties :

Every mineral has an orderly arrangement of atoms and a definite chemical composition which gives it a unique set of physical properties, there for each mineral has its own specific properties that can be used to identify it. and this properties include :

1- Structure of minerals: results from the orderly geometric spatial arrangement of atoms in the internal structure of a mineral. This crystal structure is based on regular internal atomic or ionic arrangement that is often expressed in the geometric form that the crystal takes. Even when the mineral grains are too small to see or are irregularly shaped, the underlying crystal structure is always periodic and can be determined by

X-ray diffraction. Minerals are typically described by their symmetry content.

2- Luster: indicates how light reflects from the mineral's surface, with regards to its quality and intensity. There are numerous qualitative terms used to describe this property, which are split into:

- **a- Metallic luster :** For minerals that have refractive index greater than (3) , for example metallic minerals especially native elements such as gold and silver.
- **b- Sub-metallic luster :** For minerals that have refractive index equal to approximately (3) , and its dark to semi dark such as hematite .
- **c- Non-metallic luster :** For non-dark or transparent minerals as well as the minerals that have refractive index less than (2.6). this type contains most minerals and include :

1- ***Adamantine:*** such as in diamond and zircon .

2- ***Vitreous:*** which is a glassy luster very common in silicate minerals.

3- ***Pearly:*** such as in talc .

4- ***Resinous:*** such as in serpentine and garnet.

5- ***Silky:*** which common in fibrous minerals such as in species fibrous of gypsum .

6- ***Greasy:*** such as in nepheline .

7- ***Waxy:*** such as in opal .

8- ***Earthy or Dull:*** such as in clay minerals .

The transparency of a mineral describes the ability of light to pass through it. *Transparent* minerals do not diminish the intensity of light passing through it . An example of such a minerals are halite, gypsum and muscovite (potassium mica); some varieties are sufficiently clear to have been used for windows. *Translucent* minerals allow some light to pass, but less than those that are transparent, smoky quartz and nephrite are examples of minerals with this property . Minerals that do not allow light to pass are called *opaque* such as galena , pyrite and graphite.

3- Color: The color of a mineral is a physical property that is easy to observe. Color can only be used for a few minerals that have their own specific color . The color of a mineral alone does not usually give enough information to make a definite identification. Some minerals come in many colors . For example, slight impurities in the mineral quartz (SiO_2) give it a variety of colors.

4- Streak: It is the color of a mineral in its powdered form and is obtained by rubbing a mineral across a piece of unglazed porcelain called streak plate. Although the color of a mineral may vary from sample to sample, but the streak usually does not vary.

5- Cleavage: By definition, minerals have a characteristic atomic arrangement. Weakness in this crystalline structure causes planes of weakness, and the breakage of a mineral along such planes is termed cleavage. The quality of cleavage can be described based on how cleanly and easily the mineral breaks; common descriptors, in order of decreasing quality, are "perfect", "good", "distinct", and "poor". In particularly transparent mineral, or in thin-section, cleavage can be seen a series of parallel lines marking the planar surfaces when viewed at a side.

Cleavage is not a universal property among minerals; for example, quartz, consisting of extensively interconnected silica tetrahedra, does not have a crystallographic weakness which would allow it to cleave. In contrast, micas, which have perfect basal cleavage, consist of sheets of silica tetrahedra which are very weakly held together. As cleavage is a function of crystallography, there are a variety of cleavage types:

a- One set of cleavage : Such as mica minerals (muscovite, biotite) , that have clearly and perfect cleavage with one direction there for they cleave to form thin and flat sheets .

b- Two set of cleavage : such as pyroxene , where the two cleavage directions orthogonal , and amphibole , where the two cleavage direction non-orthogonal and formed two angles (124° , 56°) between them .

d- Three set of cleavage : Either the three cleavage directions orthogonal, such as halite mineral, or non-orthogonal (orthorhombic) such as calcite mineral .

6- Fracture : When a mineral is broken in a direction that does not correspond to a plane of cleavage, it is termed to have been fractured. There are several types of fracture:

a- conchoidal fracture: The classic example, like that of quartz; rounded surfaces are created, which are marked by smooth curved lines. This type of fracture occurs only in very homogeneous minerals.

b- Hackly fracture: describes a break along a rough, jagged surface; an example of this property is found in native copper.

c- Fibrous fracture : such as Fibrous gypsum and asbestos .

d- Uneven fracture: Irregular or rough surfaces such as (Bornite Cu_5FeS).

7- Hardness : The hardness of a mineral defines how much it can resist scratching. This physical property is controlled by the chemical composition and crystalline structure of a mineral.

The most common scale of measurement is the ordinal Mohs hardness scale. Defined by ten indicators, a mineral with a higher index scratches those below it. The scale ranges from talc, a phyllosilicate, to diamond, a carbon polymorph that is the hardest natural material. The scale is provided below:

Mohs hardness	Mineral	Chemical formula
1	Talc	Mg3Si4O10(OH)2
2	Gypsum	CaSO4·2H2O
3	Calcite	CaCO3
4	Fluorite	CaF2
5	Apatite	Ca5(PO4)3(OH,Cl,F)
6	Orthoclase	KAlSi3O8
7	Quartz	SiO2
8	Topaz	Al2SiO4(OH,F)2
9	Corundum	Al2O3
10	Diamond	C

8- Specific Gravity (Density) : Density is the mass in a given space, or mass per unit volume. Each mineral has a specific density, No matter how large or small the sample of a mineral is, its density will remain the same. On the other side if you have two minerals of the same size one might be heavier than the other, for example galena will be three times heavier than the same size of quartz.

Density= Mass/Volume (D = M / V) .

Mass is the amount of matter in an object or material and is measured in milligrams, grams, or kilograms .

Volume is the amount of space that an object or material fills and is measured in milliliters (cm^3) or liters (m^3) .

As long as the density is mass divided by volume so density is typically measured in grams per milliliter (g/ml or g/cm^3) .

The density of liquid water is 1.0 grams per milliliter (1.0 g/ml), therefore anything more dense than 1.0 g/ml sinks in water and anything less dense than 1.0 g/ml floats in water .

Geologists measure density by the following:

- First they use a balance to determine the mass of a sample.
- Second, they place the mineral in water to see how much water it displaces, where the volume of displace water = the volume of the sample .
- Third they use the following formula :

  Density = Mass/Volume .

In general, the mineral is described by estimating its weight by hand, whether it is heavy, medium, heavy or light.

9- **Other properties:** Other properties can be used to identify some minerals. For example:

Halite (NaCl) is ordinary table salt. It can be identified with your tongue. And talc ($Mg_3Si_4O_{10}(OH)_2$) feels soapy. Some varieties of magnetite (Fe_3O_4) are natural magnets. And certain minerals will effervesce (fizz) when hydrochloric acid is added Calcite ($CaCO_3$). Some minerals can also be tested for smell such as Sulfides have a characteristic smell, especially as samples are fractured, reacting, or powdered.

-Classification of minerals

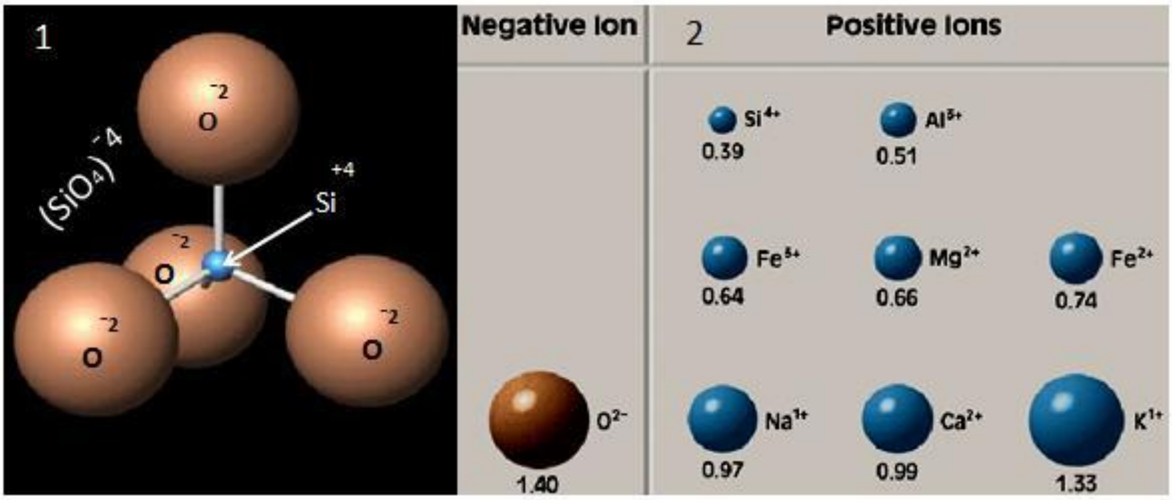
The easiest and simpler classification is that based on chemical composition of minerals terms of its content silica whether or not , on this basis , the minerals divided in to two classes: silicates and non-silicate minerals, each class include numbers of mineral groups .

As the composition of the Earth's crust is dominated by silicon and oxygen, silicate minerals are by far the most important class of minerals in terms of rock formation and diversity. However, non-silicate minerals are of great economic importance, especially as ores.

A-Silicates:

This class includes large numbers of mineral groups and the most distribution in nature (more than 90% from earth's crust) , the minerals of this class also features a complex in chemical composition , in addition to contain silicon and oxygen (silica) in its chemical composition .

The base unit of a silicate mineral is the $[SiO4]^{4-}$ tetrahedron .In the vast majority of cases, silicon is in four-fold or tetrahedral coordination with oxygen (that is, a silicon cation coordinated by four oxygen anions), as shown in fig.



Silicon-oxygen tetrahedron with some of positively charged ions.

The bond between silicon and oxygen atoms in tetrahedron is 50% ionic and 50% covalent . It is known that the tetrahedron bonding of silicon and oxygen is connected with each other and by combining positively charged elements such as magnesium, sodium and potassium with oxygen atoms by sharing one , two , three or four atoms to give a complex structure of silicates , such a link between the tetrahedrons of silicates by sharing oxygen atoms called polymerization.

Depending on the degree of polymerization in the chemical structure, the silicate minerals are divided into:

1- Quartz group (SiO_2) : Quartz mineral is formed In the normal conditions (temperature and pressure) . This group also includes a number of other minerals with the same structure SiO_2 but under higher pressure and temperature conditions will have different names such as Cristobalite , Coesite and Steshovite . In this group (Si : O = 1 : 2) .

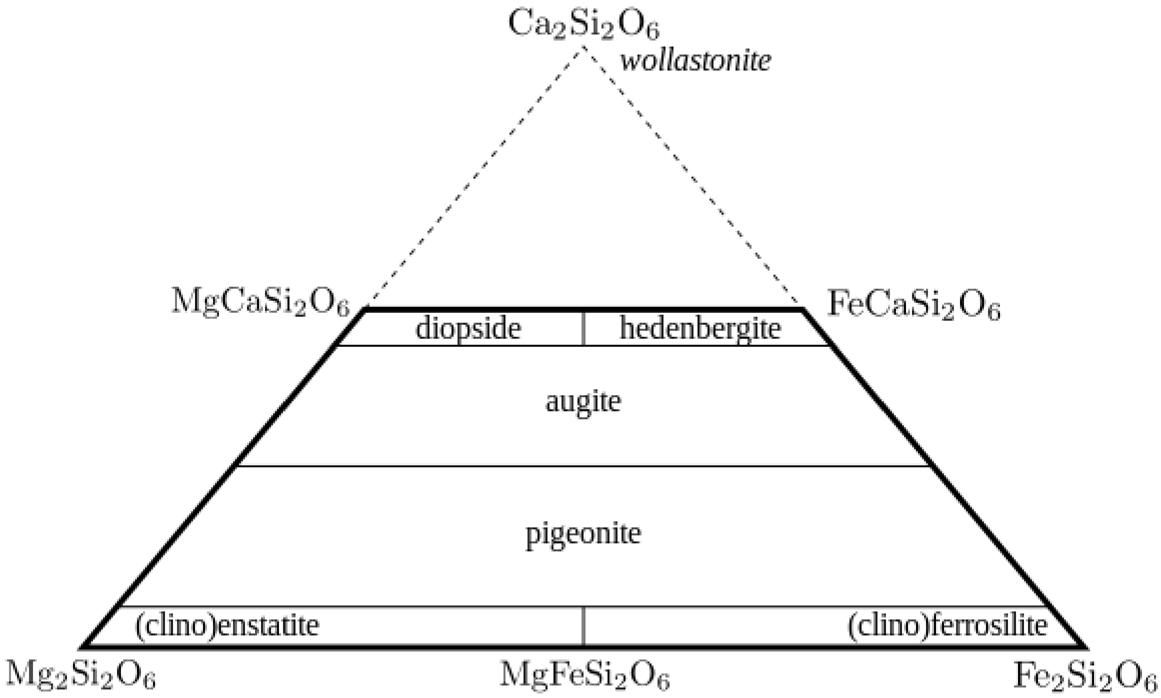
2- Feldspars group : This group is divided into two main parts:

a- *Alkali Feldspars* : such as Orthoclase ($KAlSi_3O_8$) .

b- *Plagioclase* : It contains a series of crystallized minerals in a solid solution from the melt and which starts with calcium rich in the form of Anorthite mineral ($CaAl_2Si_2O_8$) , and ends with sodium rich in the form of Albite ($NaAlSi_3O_8$). In this group (Si : O = 3 : 8) .

3- Feldspathoids group : This group is similar to the feldspars group in terms of components , but it contains less silica than the Feldspars, which means that it formed from a non-saturated silica melt. For example, the mineral of the Nepheline ($NaAlSiO_4$), which is observed in terms of containing the elements of sodium and aluminum, it is similar to Albite ($NaAlSi_3O_8$), but the proportion of silica is less than in Nepheline . Also Leucite mineral ($KAlSi_2O_6$), which is similar to orthoclase (Alkali Feldspar) ($KAlSi_3O_8$) in terms of containing the elements of potassium and aluminum, but the proportion of silica less in leucite.

4- Pyroxenes group : It is a group that includes many minerals and can be understood simple examples, especially those that represent the corners of the triangle known for the designation of minerals This group, which is characterized by (Si : O = 1 : 3) .



The nomenclature of the calcium, magnesium, iron pyroxenes .

5- Olivines group : Such as magnesium-rich olivine named Forsterite (Mg_2SiO_4) and iron-rich olivine called Fayalite (Fe_2SiO_4) **.** In this group (Si : O = 1 : 4) .

It should be noted that the all previous five groups of silicate minerals are anhydrous silicates because it does not contain water (root of hydroxyl (OH)) in their chemical composition , while the following two groups (Amphiboles and Micas) are hydrous silicates because they contain water in their chemical composition .

6- Amphiboles group : A large group of hydrous silicates complex installation, the most important example of this group : Anthophyllite: $(MgFe)Si_8O_{22}(OH)_2$, Tremolite : $(Ca_2Mg_3)Si_8O_{22}(OH)_2$, and The famous mineral in this group is Hornblende : $(CaMg)(FeAl)Si_8O_{22}(OH)_2$. In this group (Si : O = 4 : 11) .

7-Micas group : It is also a hydrous silicates. Examples are: Muscovite: $(KAl_3)Si_3O_{10}(OH,F)$ and Biotite : $K(MgFe)_3(AlSi_3)O_{10}(OH,F)$.

B- Non-silicates : Includes the following groups:

1. **Native Elements :** Named by that name because it is free in nature and composed of one element may be metallic or non-metallic. Such as: gold (Au), silver (Ag), sulfur (S) , diamond (C), graphite (C) and others.
2. **Sulfides group :** This group contains the sulfur element in its chemical composition. Such as galena (PbS) and pyrite (FeS_2) .
3. **Sulphates group :** Contains the sulphate root ($SO_4^{=}$) in its chemical composition. Such as gypsum ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$) .
4. **Oxides group :** Contains the oxygen in its chemical composition. Such as magnetite (Fe_3O_4), hematite (Fe_2O_3), illmenite ($FeTiO_3$), corundum (Al_2O_3) and rutile (TiO_2) .
5. **Hydroxides group :** Contains water in form hydroxyl root (OH^-) . Such as brucite $Mg(OH)_2$.
6. **Carbonates group :** Contains the carbonate root ($CO_3^{=}$) in its chemical composition. Such as calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$].
7. **Halides group :** Contains the halogens in its chemical composition . Such as halite or so-called salt (NaCl) , and fluorite (CaF_2) .
8. **Phosphates group :** Contains the phosphate root (PO_4^{-3}) in its chemical composition. Such as Apatite $Ca_5(PO_4)_3(F,OH,Cl)$.

Petrology

scientific study of rocks that deals with their composition, texture, and structure; their occurrence and distribution; and their origin in relation to physicochemical conditions and geologic processes. The term petrology , a Greek word, consists of two parts: the first *petro* means the rock, and the second the *logos* means science.

-Rock : is a natural substance, a solid aggregate of one (monomineralic) or more (polymineralic) minerals or mineraloids. Examples of monomineralic -rock: the dunite (igneous rock) consisting of olivine mineral , Limestone , gypsum (sedimentary rocks) consisting of calcite and gypsum minerals respectively, and quartzite (metamorphic rock) consisting of quartz mineral .

-Operations responsible for rock formation:

For the purpose of understanding the major divisions or classes of rocks, the processes responsible for their formation must be understood. These processes are also called genetic classification or also called deposition environments:

1- **Igneous processes :** include briefly crystallization of minerals from high-temperature silicate melt known as magmas.

2- **Metamorphic processes :** include re-crystallization of minerals and their interaction in the original rocks are in the solid state under high temperature and pressure conditions provided there are no melting.

3- **Sedimentary processes :** These processes occur on rocks of any type (igneous, metamorphic or sedimentary) alternately starting with the process of weathering which results in the sediments and through the process of transportation of the sediments (the weathering products) and then the process of sedimentation or deposition and finally the lithification .

On this basis, as a natural result of the above processes will consist of three classes of rocks forming the earth : igneous , sedimentary and metamorphic rocks .

1- Igneous Rocks are formed as a result of the solidifies of melting matter by the process of crystallization that occurs as a result of cooling melt when penetrating the crust layers. This high-temperature melt rises up toward the surface of the earth to harden by cooling, either very quickly to suddenly reach the surface to give extrusive rocks (also called volcanic rocks) , or solidify this melt in the earth's cavity as it penetrates the Earth's layers slowly to give the intrusive rocks (also called plutonic rocks) . The texture of these two types of igneous rock will vary due to the different cooling speed, The volcanic rocks will be fine crystallized or have a glassy (amorphous) texture due to very rapid or sudden cooling, respectively, but The plutonic rocks will have a coarse texture, ie coarse crystals, due to the slow cooling of the melt. In the first case there is not enough time to form the crystals, while in the second case there will be enough time to crystallize .

2- Sedimentary Rocks are formed by successive processes of weathering, transport and sedimentation in different sedimentation environments (marine, continental, river, etc.). Sedimentation occurs in these different environments in the bottoms of seas and oceans or on land by sedimentation of suspended, portable and transported sediments with varying grain size (fractions of weathering rocks) such as river sediments or some marine sediments because of the inability of the water current carrier to carry them farther distances because of their weight , or sedimentation may occur due to chemical reactions of substances transported in the form of dissolved ions in water and usually formed after sedimentation of layers (beds or strata) of sedimentary rocks, in the first case called clastic sedimentary rocks, while In the second case they are called non-clastic sedimentary rocks or are also called chemical sedimentary rocks .

Sedimentary rocks layers may contain the remains of organisms called fossils or organic remains, This will give us a third type of rock called organic sedimentary rocks.

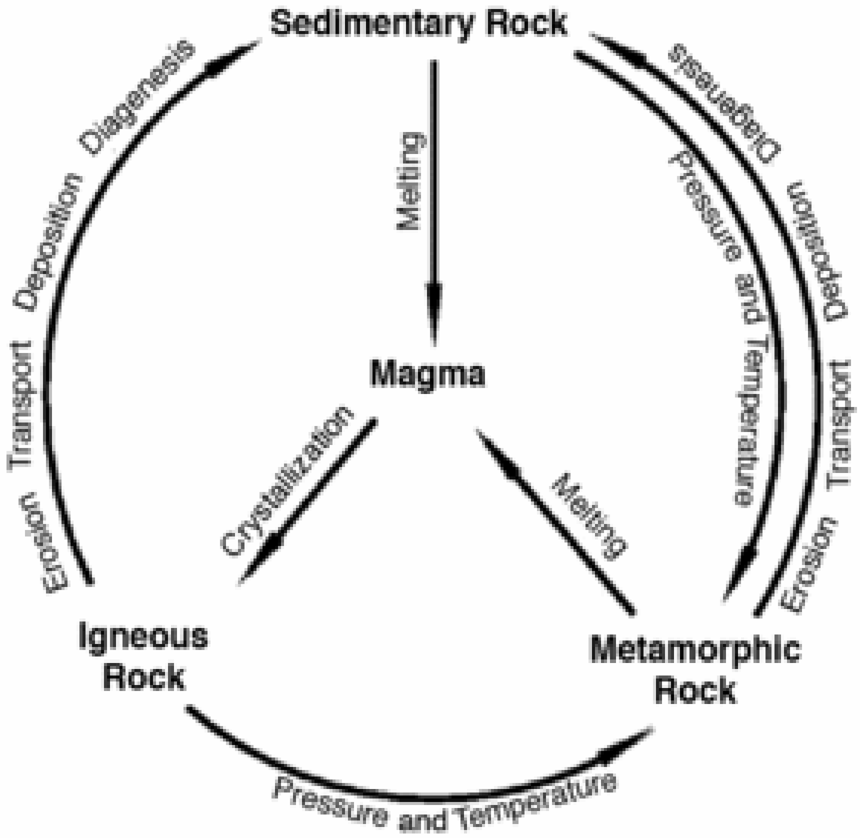
3- Metamorphic Rocks are formed from the transformation of rocks were in the origin of igneous, sedimentary or even metamorphic by the factors controlling metamorphism (pressure, heat and chemical agents) are working to re-crystallize the original rocks (parent rocks) in the solid state provided that it does not melt . This process of re-crystallization will, in turn, give the metamorphic rocks, which will either be regionally metamorphic rocks as a result of regional metamorphism (by pressure and heat**) ,** or contact metamorphic rocks as a result of contact metamorphism, also called thermal metamorphism, (by heat only) , or cataclastic metamorphic rocks as a result of dynamic metamorphism (by pressure only) .

These three types of rocks (igneous, metamorphic and sedimentary) will be explained in detail later.

Rocks cycle:

The rock cycle is an important concept in geology which illustrates the relationships between these three types of rock, and magma. When a rock crystallizes from melt (magma and/or lava), it is an igneous rock. This rock can be weathered and eroded, and then redeposited and lithified into a sedimentary rock, or be turned into a metamorphic rock due to heat and pressure that change the mineral content of the rock which gives it a characteristic fabric. The sedimentary rock can then be subsequently turned into a metamorphic rock due to heat and pressure and is then weathered, eroded, deposited, and lithified, ultimately becoming a sedimentary rock. Sedimentary rock may also be re-eroded and redeposited, and metamorphic rock may also undergo additional metamorphism. All three types of rocks may be re-melted; when this happens, a new magma is formed, from which an igneous rock may once again crystallize.

The majority of research in geology is associated with the study of rock, as rock provides the primary record of the majority of the geologic history of the Earth.



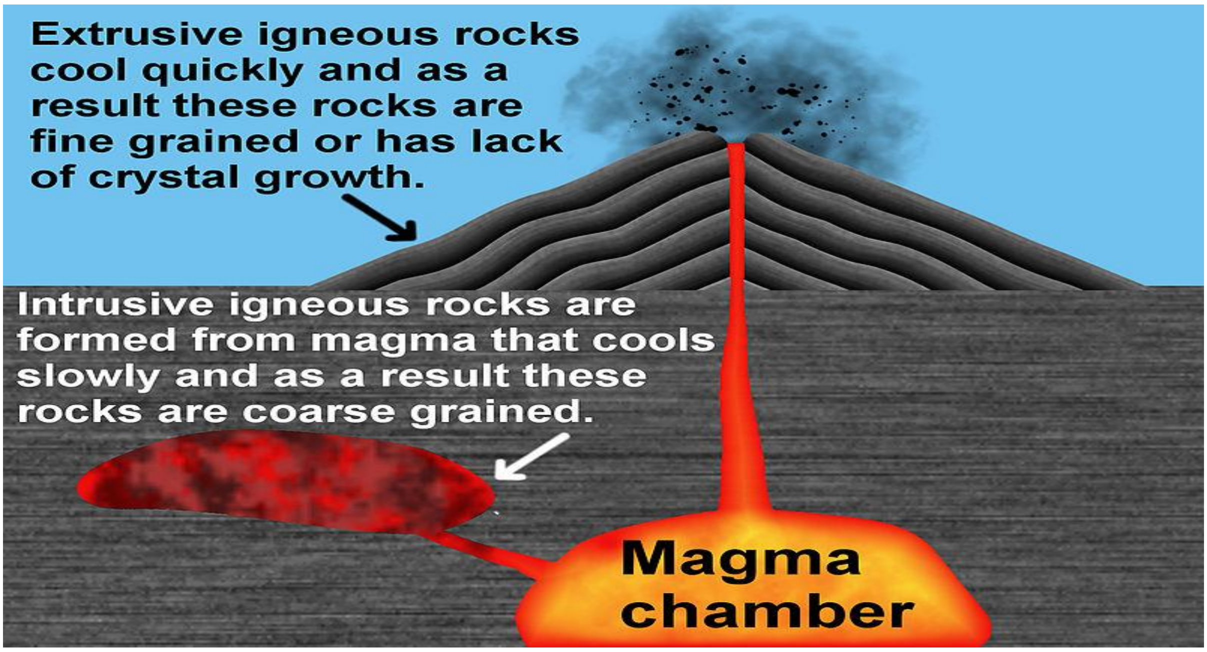
Rock cycle

IGNEOUS PETROLOGY

Igneous rock derived from the Latin word *ignis* meaning fire. In order to understand the igneous rocks, we begin to define the ***magma***, that is, the molten rock material (in whole or in part) in the depths of the earth, under the earth's crust and the top of the upper mantle, because of very high temperatures, and It is a silicate material Often mixed with gases and vapors such as water vapor. The very high temperature source in these places is the continuous decay of the radioactive elements that exist there in abundance, particularly the elements of thorium (Th), uranium (U) and potassium (K) . It is known that nuclear fission produces a very high thermal energy, which most scientists believe is sufficient to smelter the rocks, and the magmas are formed in specific chambers called magmatic chambers.

The magmatic chambers have a very high potential energy and will look for an outlet to be released from its potential energy generated under high pressure as well as the high temperature, and the magma will erupt and rush to the top towards the surface of the earth is a liquid or viscous through cracks in the layers of the crust either in the form Volcanic lava to form volcanoes erupting from conical volcanic craters, or crystallize in the underground before reaching the surface. After lava solidifies as a result of rapid or sudden cooling, it will consist of the extrusive rocks which are also called volcanic rocks. while If magma solidifies under the surface of the earth (underground) as a result of slow cooling will be composed extrusive rocks, also called plutonic rocks.

The texture of the igneous rocks, both types plutonic and volcanic, means the degree of crystallization of the constituent minerals or the so-called grain size of these minerals. Texture of plutonic rocks will be coarse because slow cooling will allow time for crystallization and the growth of fine crystals to form crystals or granules of coarse size, While the volcanic rock texture will be fine when the cooling is relatively slow or glassy when the cooling is so sudden that there is not enough time for the crystals to grow fine or not originally formed, it will be like glass.



Forming of igneous rock

- Classification of Igneous Rocks :

There are many classifications of igneous rocks, but what we are interested in is chemical classification and mineral classification, which are the basis for the designation of igneous rocks.

- Chemical classification :

It includes several types, we will only mention two of them, because of its importance:

A) According to ratio of silica SiO_2 : This method of classification was adopted by the Russian scientist Leewinson-Lessing in 1897 and is still reliable. After the chemical analysis of the igneous rocks, the silica content is found. According to this content, the igneous rocks were divided into four types:

1- <u>Acidic rocks</u> : Contains more than 66% SiO_2 .

2- <u>Intermediate rocks</u> : where 52-66% SiO_2 .

3- <u>Basic rocks</u> : where 45-52% SiO_2 .

4- <u>Ultrabasic</u> rocks : where SiO_2 less than 45% .

B) According to silica saturated : If a magma is oversaturated with respect to Silica then a silica mineral, such as quartz, cristobalite, tridymite, or coesite, should precipitate from the magma, and be present in the rock. On the other hand, if a magma is undersaturated with respect to silica, then a silica mineral should not precipitate from the magma, and thus should not be present in the rock. The silica saturation concept can thus be used to divide rocks in **silica oversaturated**, **silica saturated,** and **silica undersaturated rocks**. The first and last of these terms are most easily seen.

1- silica-oversaturated rocks : These are rocks contain quartz mineral in its mineral components because of the surplus of silica in the magma from which these rocks crystallized.

2- Silica saturated rocks : These are rocks that contain silicate minerals and do not contain quartz mineral because there is no surplus of silica in magma .

3- Silica undersaturated rocks : In these rocks we should find feldspathoids minerals such as nepheline or leucite because melt lacks silica, meaning silica not enough to form some silicat minerals such as albite and orthoclase Instead it will consist of nepheline and leucite, which need less silica.

- Bowen's Reaction Series

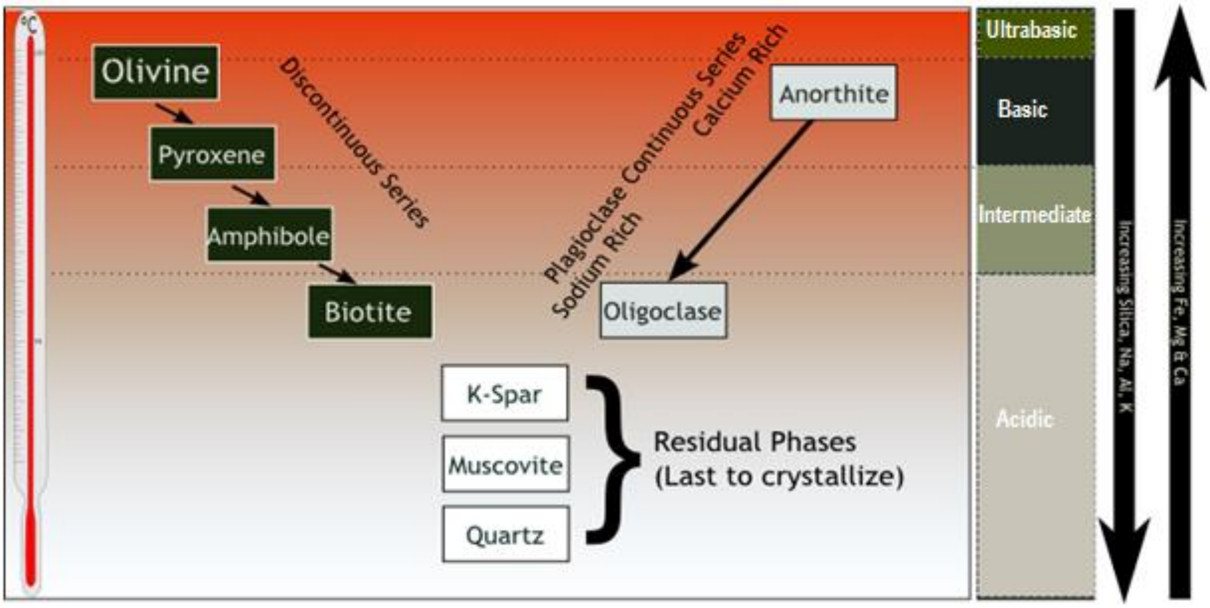
Within the field of geology, Bowen's reaction series is the work of the petrologist, Norman L. Bowen who summarized, based on experiments and observations of natural rocks, the crystallization sequence of typical basaltic magma undergoing fractional crystallization (i.e., crystallization wherein early-formed crystals are removed from the magma by crystal settling, say, leaving behind a liquid of slightly different composition). Bowen's reaction series is able to explain why certain types of minerals tend to be found together while others are almost never associated with one another. He experimented in the early 1900s with powdered rock material that was heated until it melted and then allowed to cool to a target temperature whereupon he observed the types of minerals that formed in the rocks produced. He repeated this process with progressively cooler temperatures and the results he obtained led him to formulate his reaction series which is still accepted today as the idealized progression of minerals produced by cooling basaltic magma that undergoes fractional crystallization. Based upon Bowen's work, one can infer from the minerals present in a rock the relative conditions under which the material had formed.

The series is broken into two branches, the continuous and the discontinuous. In discontinuous series the minerals were arranged according to the priority of their crystallization from the melt at high temperatures (about 1200 C°), starting with olivine, pyroxene, and so on to crystallized quartz at relatively low temperatures (about 500 C°). In contrast, the continuous series, which includes plagioclase minerals, starts with Anorthite (calcium-rich plagioclase) at high temperatures and ends in Albite (high-sodium plagioclase) at relatively lower temperatures, ie, low heat from Anorthite to the Albite. It is known that the minerals of the plagioclase group consist or change in their chemical composition as a result of the ionic substitution, where the element of sodium replaces calcium at specific rates as follows:

1- Anorthite (100-90% Ca, 0-10% Na) .
2- Bytownite (90-70% Ca) .
3- Labradorite (70-50% Ca).
4- Andesine (50-30% Ca) .
5- Oligoclase (30-10% Ca) .
6- Albite (10-0% Ca, 90-100% Na) .

The process of crystallizing the minerals from the melt is called magmatic differentiation or magmatic crystallization .

The Bowen's reaction series helps to understand the naming of igneous rocks. The importance or benefit of this series appear in the knowledge of the mineral components of each type of igneous rock. The most important point is that the constituent minerals of any igneous rock must be in a specific range of temperatures, for example, ultrabasic rocks in general contain mainly olivine and pyroxene at very high temperatures, It is wrong, for example, to say that it contains quartz because quartz is formed at low temperatures as there cannot be two different types of temperatures in one.



Bowen's Reaction Series

Description and nomenclature of igneous rocks :

In general, igneous rocks are divided into four main groups based on their mineral content. The following is a simplified explanation of these four groups :

1- Acidic rocks : These rocks are light, consisting of quartz and feldspar (orthoclase and plagioclase) mainly. It may sometimes contain a small percentage of dark-colored minerals such as Hornblende or Biotite as secondary minerals.

2- Intermediate rocks : These rocks are medium color mainly composed of Hornblende and plagioclase. It may sometimes contain a small percentage of mica , pyroxene or quartz as secondary minerals.

3- <u>Basic rocks</u> : These rocks are dark color mainly composed of pyroxene and plagioclase. It may contain olivine, hornblende or mica as secondary minerals.

<u>4- Ultrabasic rocks</u> : These rocks are dark color mainly composed of olivine and pyroxene . it may contain a small percentage of hornblende or anorthite as secondary minerals .

- Naming Igneous rocks : Based on all of the above, the igneous rocks can be named according to their mineral components and according to the following table (the examples given in the table are the simplest types of igneous rocks and distinct for the four groups mentioned above. Also, the volcanic equivalent is that the mineral components are the same as in the plutonic rocks, but its texture is different, that is, It's fine):

<u>It is noted in the table that the ultrabasic igneous rocks have no volcanic equivalents.</u>

Igneous rocks	Name of plutonic rock	Volcanic equivalent	Mineral components
Acidic	Granite	Rhyolite	Quartz , orthoclase and plagioclase in equal proportions with low percentages of hornblende or mica.
	Granodiorite	Dacite	Quartz with (plagioclase more than orthoclase) and low percentages of mica or hornblende.
Intermediate	Syenite	Trachyte	Orthoclase is mainly with low rates of plagioclase and quartz.
	Diorite	Andesite	Plagioclase with hornblende mainly with low percentage of pyroxene or quartz .
Basic	Gabbro	Basalt	Plagioclase with pyroxene mainly with low percentage of olivine or mica .
	Dolerite	Basalt	The same components of gabbro but they have different texture (Porphyritic)*.
Ultrabasic	Dunite	--------------	Olivine is mainly with very low percentage of pyroxene .
	Peridotite	--------------	Olivine and pyroxene mainly With sometimes small proportions of hornblende or plagioclase (anorthite) .
	Pyroxenite	--------------	Pyroxene mainly with sometimes very low percentage of olivine .

* The porphyritic is the texture that is formed in the rock from large crystals surrounded by small granules of the same mineral components of the rock. This means that the rock has suffered two stages of cooling. The first is a slow cooling, allowing sufficient time to form coarse crystals, followed by a second phase of cooling, a rapid cooling that did not have the opportunity to form coarse crystals instead of fine crystals surrounding the coarse. Such a texture is formed in rocks near the earth's surface, ie, in the middle depths between the plutonic (in deep) and volcanic (on the surface).

SEDIMENTARY PETROLOGY

Sediment is a naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of wind, water, or ice, and/or by the force of gravity acting on the particles. For example, sand and silt can be carried in suspension in river water and on reaching the sea be deposited by sedimentation and if buried this may eventually become sandstone and siltstone,(sedimentary rocks).

Sediments are most often transported by water (fluvial processes), but also wind (aeolian processes) and glaciers. Beach sands and river channel deposits are examples of fluvial transport and deposition, though sediment also often settles out of slow-moving or standing water in lakes and oceans. Desert sand dunes and loess are examples of aeolian transport and deposition. Glacial moraine deposits and till are ice-transported sediments.

Sediments are usually formed from matter which falls to the bottom of oceans and lakes. The matter includes tiny pieces of other rocks, and dead animals, plants and microorganisms. Also, inorganic chemicals may be precipitated from solution in the water as a result of chemical reactions of dissolved ions in water or as a result of the complete evaporation of water containing these dissolved ions. These are called chemical sediments.

- Processes of sedimentation :

These are all the processes that occur on the original rock exposed on the surface of the earth in all its forms and, they are alternating: weathering and then transport and sedimentation to give the sediments that finally harden to give sedimentary rocks. Sedimentary processes are:

1- **Weathering :** Is the process of fragmentation of ancient rocks exposed to the surface of the earth to particulates small size by several factors . There are three types of weathering :

a- Mechanical weathering : Including rain, floods and even the wind, as well as other factors such as the heat of the sun, which works to crack mud, for example, after drying, making it easy to break into small pieces. Also include factors that crystallize the salts in the rock cracks and melt, and freeze the water inside the layers, which leads to cracking and then disintegration, or by the roots of plants that penetrate the soil.

b- chemical weathering : Involves rock solubility in the form of ions dissolved in water containing oxygen and carbon dioxide, and there are other factors such as oxidation, ionic exchange, dissolution, hydration and carbonization.

c- organic weathering : Is carried out by organisms such as bacteria and lichens.

It should be noted here (in weathering) that the minerals formed by the magmatic crystallization of according to Bowen's reaction series for the discontinuous series, starting with olivine in the early stages of crystallization and end with quartz in the final stages, have a resistance to weathering in contrast to the arrangement. In other words, the finally formed quartz is a strong resistance to weathering. This resistance is reduced to the first olivine, which is the first to be less resistant to weathering, and is breaks up quickly by the weathering factors, while the quartz does not dissolve in water. This is due to the strength of the cohesion of its atoms, which outweigh the cohesion of olivine atoms.

2- **Transportation :** The transport of weathering products is carried out either by wind in desert environments or by water in areas of rivers, tributaries, areas of snow and rainfall on land . In water, it is transported in the form of suspended, colloidal or dissolved substances to their sedimentation sites. The suspended materials are transported into the water in small, portable fragments like clay, sand, and fine pebbles, while the coars fragments will roll down the riverbed in the form of rolling materials called *traction* because they are difficult to carry du to their weight. In this way, the sharp edges of the rock blocks will be eroded, increasing their rotation as long as the transport distance. Whilst the rock masses that do not exceed the size of pebble and at the same time larger than the size of sand, it is transported by the saltation and depends on the density of water (carrier medium) and the density of transported blocks.

3- Deposition or sedimentation : The transported materials (portable) are deposited in one of the following sedimentation methods:

a- Mechanical deposition : Occurs when the transport agent (water or wind) is weakened , ie, when the speed of the river or wind decreases . The suspended material (natural weathering products) is deposited when the water current is low as a result of the presence of obstacles in the course of the river carrier such as the narrowness of the riverbed, twisting or increasing the load which leads to falling materials suspended at the bottom of the river forming the so-called *clastic deposits of pebble, sand and clay*.

b- Chemical deposition : is obtained by chemical reactions of chemical weathering products (dissolved ions) in the conveyor solutions and in certain deposition environments and under appropriate conditions . The following interaction represents examples of chemical deposition :

$$2Na^{+} + CO_3^{=} + Ca^{++} + 2Cl^{-} \longrightarrow CaCO_3 \downarrow + 2NaCl$$

Deposit (calcite)

$$2Fe^{++} + 2OH^{-} + \frac{1}{2}O_2 \longrightarrow Fe_2O_3 \downarrow + 2H_2O$$

Deposit (hematite)

$$Ca^{++} + 2HCO_3^{-} \longrightarrow CaCO_3 \downarrow + H_2O + CO_2 \uparrow$$

Deposit (calcite) gas

These deposits called *non-calstic or chemical deposit*, and after hardening, the limestone consisting mainly of (calcite) and iron ore (hematite) will be formed.

c- <u>The organic deposition</u> : occurs when organisms absorb some substances or solutions dissolved in water or colloidal solutions and settle these substances in their skeletal structures or shells. After the death of these organisms, their structures are composed of organic sediments, and after their solidification, deposits such as phosphate or organic limestone containing calcareous shells form.

4- Lithification : Is the process of cohesion the sediments mentioned above after exposure to natural and chemical factors which make the granules sediments closer and cohesive then solidifying to form sedimentary rocks. There are several factors for lithification : *compaction* , *cementation* , *crystallization and heating* . Each factor has an important role, but the process of *cementation* is the most important process, where the sediments cohesion by additional cement material such as carbonates, gypsum or iron oxides which fills the gaps between sediment granules and increases their cohesion and hardness. After the completion of the process of lithification will give us the three types of sedimentary rocks, which are **clastic, chemical** and **organic.**

- Classification of sedimentary rocks : According to all sedimentary processes that mention above , the sedimentary rocks classified in to :

1- **Clastic sedimentary rocks :** Clastic sedimentary particles and sedimentary rocks are classified in terms of grain size and shape, among other factors ,as show in the following table :

Name of Particle	Size Range (mm)	Loose Sediment	Consolidated Rock
Boulders	>256	Gravel	Conglomerate or Breccia (depends onrounding)
Cobbles	256-64	Gravel	
pebbles	2-64	Gravel	
Sand	1/16 - 2	Sand	sandstone
Silt	1/256 - 1/16	Silt	siltstone
Clay	<1/256	Clay	Claystone, mudstone, and shale

In general, the coarser sediment gets left behind by the transportation process. Thus, coarse sediment is usually found closer to its source and fine grained sediment is found farther from the source.

2- **Chemical sedimentary rocks :** Dissolved ions released into water by the weathering process are carried in streams or groundwater. Eventually these dissolved ions end in up in the ocean, explaining why sea water is salty. When water evaporates or the concentration of the ions get too high as a result of some other process, the ions recombine by chemical precipitation to form minerals that can accumulate to become chemical sediments and chemical sedimentary rocks. Among these are:

a- Evaporites : Formed by evaporation of sea water or lake water. Produces halite (salt) and gypsum deposits by chemical precipitation as concentration of solids increases due to water loss by evaporation.

b- ***Travertine :*** Groundwater containing dissolve calcium and bicarbonate ions can precipitate calcite to form a chemically precipitated limestone, called travertine. This can occur in lakes, hot springs, and caves.

c- ***Dolostones :*** Limestone that have been chemically modified by Mg-rich fluids flowing through the rock are converted to dolostones. $CaCO_3$ is recrystallized to a new mineral dolomite $CaMg(CO_3)_2$.

d- ***Chemical Cherts :*** Groundwater flowing through rock can precipitate SiO_2 to replace minerals that were present. This produces a non-biogenic chert. There are many varsities of such chert that are given different names depending on their attributes, For example:

Flint – Black or gray from organic matter.

Jasper – Red or yellow from Fe oxides.

3- Organic sedimentary rocks : When the organism dies, the remains can accumulate to become sediment or sedimentary rock. Among the types of rock produced by this process are:

a- ***Organic Limestone :*** Calcite ($CaCO_3$) is precipitated by organisms usually to form a shell or other skeletal structure. Accumulation of these skeletal remains results in a limestone. Limestones are very common sedimentary rocks.

b- ***Organic Chert :*** Tiny silica secreting planktonic organism like Radiolaria and Diatoms can accumulate on the sea floor and recrystallize during lithification to form biochemical chert.

c- ***Diatomite :*** When diatoms accumulate and do not undergo recrystallization, they form a white rock called diatomite .

d- ***Coal :*** Is an organic rock made from organic carbon that is the remains of fossil plant matter. It accumulates in lush tropical wetland settings and requires deposition in absence of oxygen. It is high in carbon and can easily be burned to obtain energy.