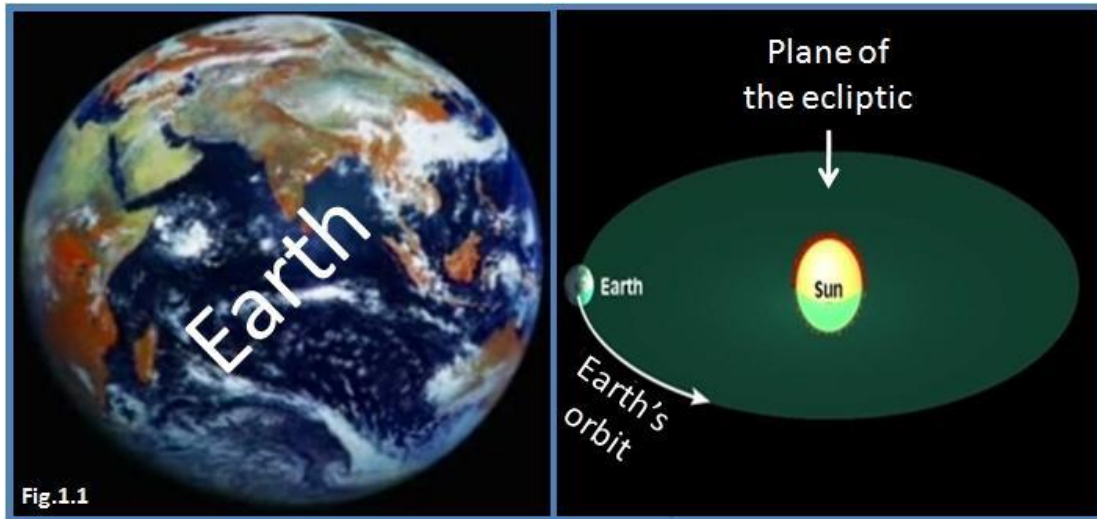


1.1-Geology:

It is a science that looks at the earth and their covers, in terms of the composition and the factors affecting them and their history.(Fig.1.1).



1.2-The importance of geology:

- 1- Disclosure of sources of energy such as oil, natural gas and minerals.
- 2- Determining the appropriate places for construction of dams , bridges and other Construction projects. (Fig.1.2).1.
- 3- Prospecting for natural mineral resources such as gold, silver, copper, lead, iron, aluminum, nickel, phosphate and halite.2.
- 4- Relocate the raw materials for construction such as sand, gravel, limestone, marble and chemical industries, such as sulfur, calcium, sodium and chlorine, which are used in the manufacture of drugs and pesticides and fertilizers.
- 5- The large increase in the number of the population, especially in the arid and desert areas has led to the search for other sources such as undergroundwater.
- 6- The possibility of the cause of the occurrence of natural disasters such as volcanoes, earthquakes and floods, as well as the prevention of landslides and buildings cracked.
- 7- Identify natural barriers as well as the best ways to move soldiers and military vehicles and identify suitable sites for digging trenches and building military bases.

1.3- A brief summary of geology:

The Greeks of the oldest philosophers interested in studying geological phenomena on the earth's surface such as mountains, high and low seas, volcanoes and earthquakes .They include:

- Thales (636-546 B.C):

- Considered the earth flat disk surrounded by water. - He believes that water is the source of all the materials in the earth through the river sediments in estuaries. He imagined that the movement of water caused earthquakes.

- Anaximander:(610-547 B.C):

-He thinks that the earth is a cylindrical shape. -The development of human and animal originally from Fish.

-Making the first map of the known world in his day.

-Think the air is the source of all materials.

- Xenophanes (540-510 B.C):

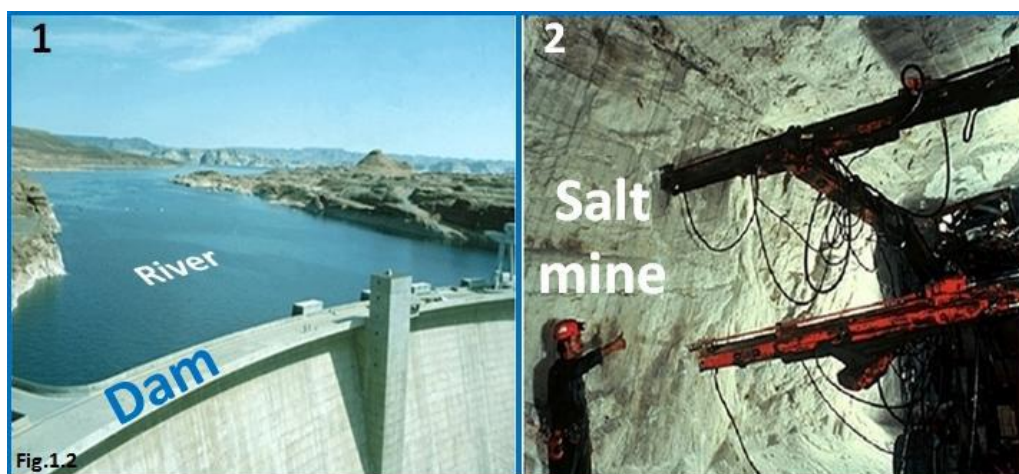
Concluded that the fossils out of the sea and the land and sea were integrated within a specific period of time.

- Plato (427-347 B.C) and (Pythagoras 582-500 B.C):

They were believed that the form of the ground ball and the spherical shape is the optimal shape.

- (Aristotle 384-322 BC):

Concluded the same truth about the spherical earth during Note spherical Earth's shadow on the moon during a lunar eclipse.



- Some Greeks philosophers are aware of the facts and the most prominent of the earth's surface has been exposed to the ups and downs and it is constantly changing.

-At the time of the Roman Empire (27 BC -935 AC), Romans did not show sufficient attention to the natural sciences. Greek Considered pure science fiction. Among the most prominent scientist of the Romans (Pliny) in the first century AD and has a (73) books in the natural sciences which (5) to study minerals.

- (Dark period in Europe 500-1100 AD):

During this period, books disappeared philosophers of the Greeks in the midst of chaos and ignorance, rivalry and sorcery and the peoples of Europe remained under the whip as slaves and the oppression and tyranny. On the other side of the world in Baghdad, Cairo and Cordoba dawned the light of learning, knowledge and civilization and rose through the voices of values and logic, philosophy, and contributed to the dissemination of progress and prosperity landmarks.

- Geology in the Arab civilization:

Arab scientists benefited of Greece theories (Greeks), which were based on the philosophy and logic. The Arabs added to a lot of scientific knowledge-based views of various natural phenomena and interpret scientific ways.

The most famous Arab scholars:

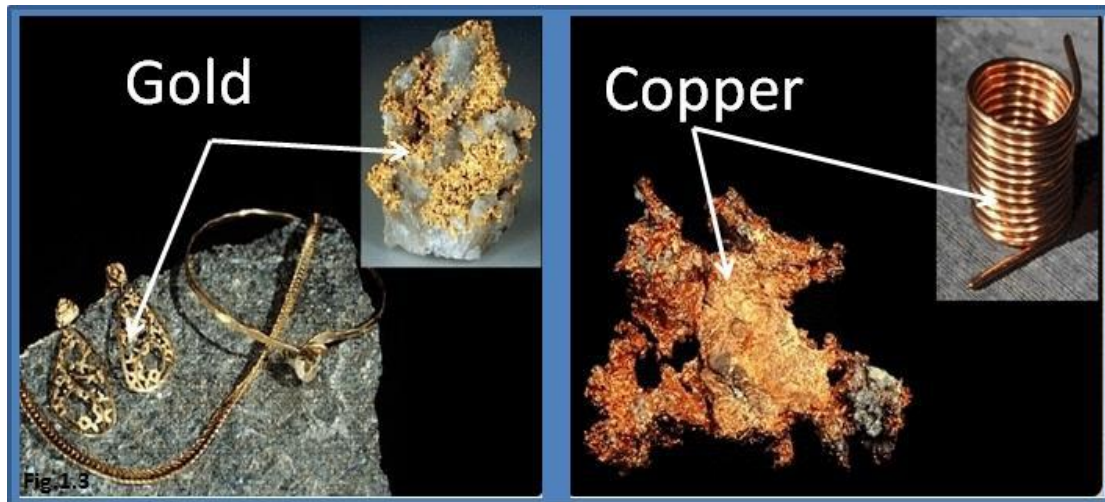
-Ibin Siena (Abu Ali Hussein 980-1037 AD):

The first Arab scientist in geology. Said his letter (Minerals and effects upper) in the book (labrum) sources of scientific task that was adopted by the Arabs after the Middle Ages has been translated into Latin Year (1068 AD).

He was the first in his theory (that the origin bullet rocks and water).Possible Ibn Sina considered the founder of the law of succession of layers. Gave Ibn Sina time factor role in transforming the different sediment to the different rocks. Has also been among that reason mountains configuration is as a result of sea sediments. He has also messages about Earthquake in match some of them with modern ideas.

Ibn Siena Put Minerals in four sections:

- 1 - Precious.
- 2 - Fuses (minerals that are fused).(Fig.1.3).
- 3 - Alkabart (metal burning).
- 4 - Salts.



- **Biruni (Abu Rayhan – died in 1271 AD):** He studied the movement of the earth around the sun, the shape, and dimensions and extracted the radius of the Earth (Biruni equation) and reached results close to the results of the present. He found specific weight accurately to (18) of minerals and gemstones. He classified a group of metals on the basis of hardness and qualitative forms. He has contributions in Stratigraphy and paleontology in his book (Aljamaher in knowledge of gems).

- **Al-Masudi (Abu Hassan Ali Bin Al Hussein):**

He wrote a lot of books including a book (promoter gold and jewels metals) and explains the Earth rotated the flow of rivers, the water cycle in nature and touched the earth's rotation.

-**Al- Kindy (Abu Yusuf):**

He wrote in the types of precious gems and stones types and internal factors that affect the earth and has other messages, including two in geology.

- **Al-Addressee (Sharif died in 1164 AD):**

He wrote several books on oceanography. He used Arab terminology for the first time and can be used in all languages.

- **Al-Raze (died in 845 AD):**

Contributed in a lot of science, including geology. Among the most famous books (Secrets of Secrets), in which class metals to (6) sections by mineral properties and methods of preparation and purification materials.

There are a lot of scientists and thinkers do not have the space to explain their achievement and suffice by mentioning their names, including:

- **Zakaria AL-Quzwine (died in 1283 AD).**

- **Al-Khazeny (Abo-Mansour).**

1.4- Branches of the geology:

1- Crystallography:

Looking at the crystallization of minerals in terms of composition and chemical and physical characteristics and conditions of their existence and its benefits.

2- Mineralogy:

Specializes in the study of minerals through knowledge of their natural (physical) and chemical properties, Classification and the conditions of its existence and its benefits.

3- Petrology:

Study the rock types in terms of the origin and composition, characteristics and classification and the conditions of their existence.

4- Dynamic geology (physical):

Interested in studying the internal and external factors that lead to the formation of the natural and geological phenomena such as mountains, rocks and minerals in the earth's surface.

5-Paleontology:

Looking to find out the remnants of ancient organisms or effects of animals and plants that lived in the previous geologic time.

6- Historical geology: Specializes in studying the order of rock layers from the earliest times to the present day, where studying fossils characteristics of each layer of the sequences and arrange the calendar of the land and divided into epochs and ages and times of sequential terms by which knowledge of the distribution of water and land through different of geological ages.

7- Stratigraphy:

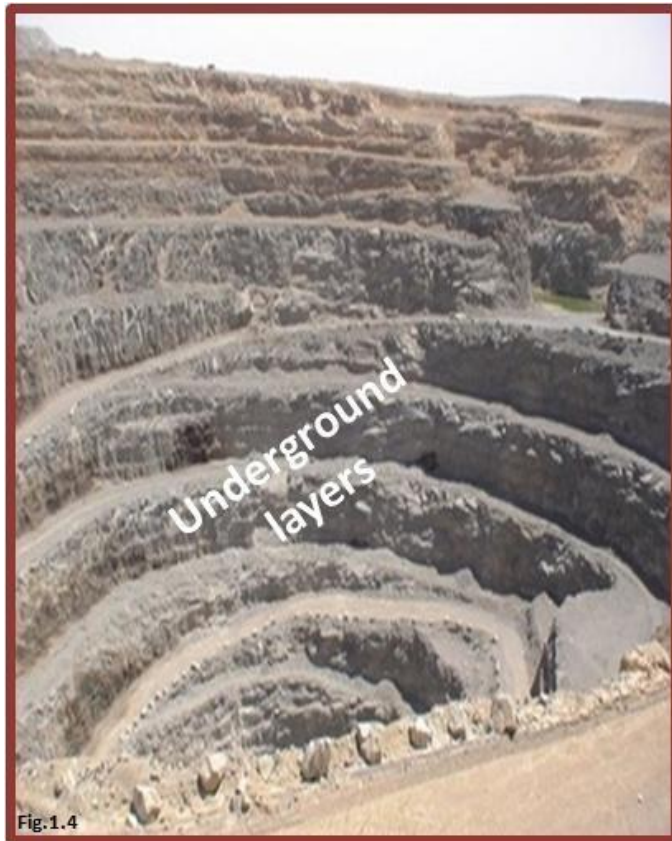
Is the science that studies the laws and deposition conditions and places of various sedimentary rock layers, and after it is fragmentation from different rocks and transported by water and air.

8- Structural geology:

Interested in studying the current construction and evolution of the earth's crust through geological ages, and explains the science reasons to configure different geological structures such as faults, fractures and joints in the rock layers as well as the reasons for the formation of the mountains.

9- Geophysics:

One of important branches in the science of the earth that specializes in the study of the underground layers of different geological formations and a private study invisible structures that could contain oil and mineral deposits of economic and water. (Fig.1.4).



10- Geochemistry:

Specialized study of minerals and rocks by chemical means and the distribution of the constituent elements of the earth's crust, as well as determine the type and proportion of mineral ores in the earth's crust.

11 - Economic Geology:

Is an applied science concerned with the search for economic resources and identified and evaluated for the purposes of benefit.

Economic Geology includes several branches, Some of them are: - **Petroleum Geology.**

- **Mining Geology.**
- **Engineering Geology.**
- **The geology of mineral deposits**
- **The geology of radioactive isotopes.**

12- Hydrogeology:

Is interested in studying the sources of surface water and groundwater and the characteristics of the physical and chemical water and study the layers of the earth containing groundwater.

13- Engineering Geology:

This includes knowledge of the mechanical and engineering properties of Earth crust and for the purpose of building bridges, dams and various facilities such as high buildings and others.

There are many disciplines that fall within the minute branches already mentioned:

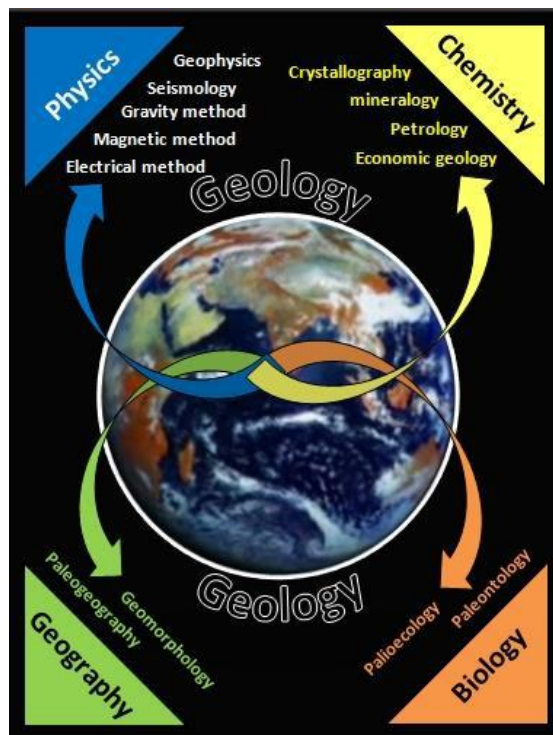
a-Geomorphology.

b-Remote sensing.

- c- Seismology.
- d-Topographic surveys.
- e- Geological Survey.
- f- Volcanology.
- g- Military Earth Science
- h- Oceanography.
- i- The study of rocks and soil of moons and planets in space.
- j- The use of automated computer in earth science studies and mapping and geological sectors.
- k- Earth Science military

1.5-Relationship between geology and other Sciences:

Note of the classification of some of the branches of Earth Science that this science develops in conjunction with other sciences such as chemistry, physics, biology, astronomy and engineering sciences as shown below:



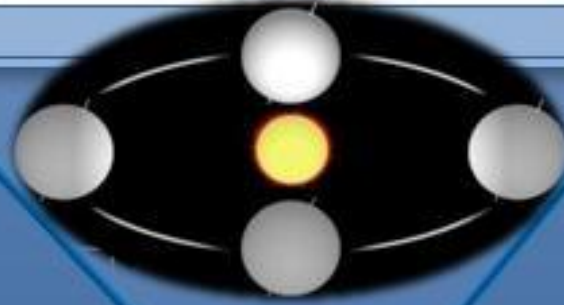
- 1- Define Earth Science (Geology).
- 2- Write five main branches and three of secondary in Earth Science.
- 3- Compare between: A- Historical geology and Paleontology B- Stratigraphy and Petrology.
- 4- What is the role of geology in the planning stage of the construction of dams in Iraq?
- 5- What is the importance of satellite imaging and remote sensing of Earth Science?
- 6- What is the nature of geologist during prospecting for oil?

- 7- There is a close relationship between geology and the others science. Discuss this statement.
- 8- Mention the most important shares of the Arab scientists in the geology?
- 9- What are the benefits of the study of the earth science?

The earth
and the solar system

Chapter two الفصل الثاني

الأرض
والمجموعة الشمسية



- Earth site in the universe.
- Planets of the solar system.
- How the solar system formed?
- Weight and time in planets.
- Earth's Moon.

- موقع الأرض في الكون.
- كواكب المجموعة الشمسية.
- كيف تكونت المجموعة الشمسية؟
- الوزن والزمن في الكواكب.
- قمر الأرض.

2.1 Earth site in the universe

The sun is the center of a huge round about system of old eight planets and it's natural moons, and many small asteroids, comets, meteorites, and dwarf planets. (fig.2.1).

The sun is a big gaseous ball, surface temperature reaches to about 6000 degrees Celsius, and it is composed of the same material consisting of the planets, but in different proportions. Hydrogen and helium Composed about 99% of the mass of the sun. Sun Star is medium-sized when compared with other stars that spread across the infinitesimal universe is finite. Sun appears to us great with respect for the rest of the other stars because it is the closest of the earth. Away from the earth, sun 149.6 million km. 1,390,549 km in diameter is equivalent to 109 times the diameter of the Earth.

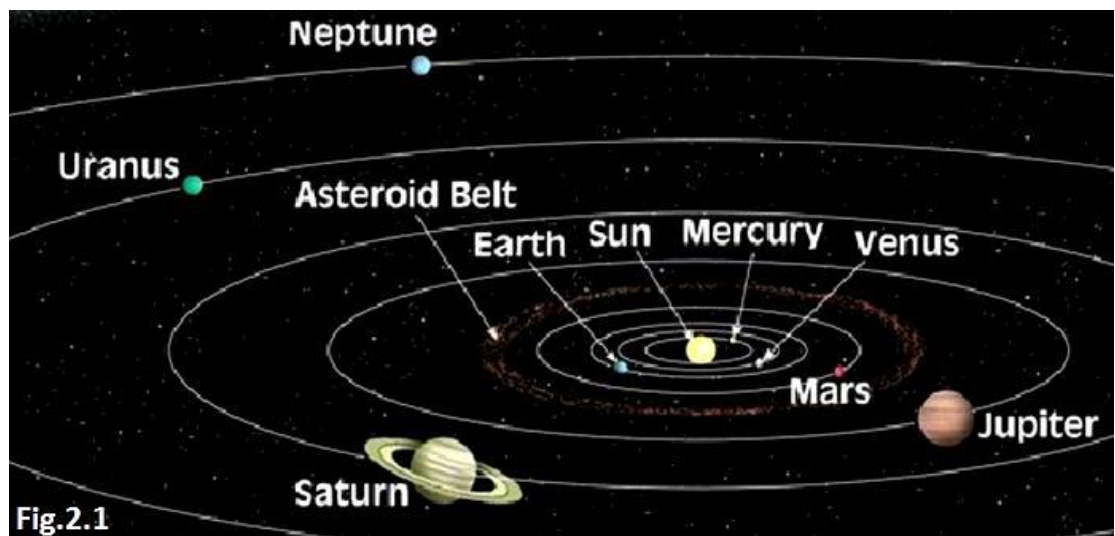


Fig.2.1

2.2- Planets of the solar system :

Plants are divided into two groups:

A- The inner planets are:

Mercury, Venus, Earth and Mars.

They are closest to the Sun and follow slightly elliptical paths.

The inner planets are also called **terrestrial** (earth-like) because they are similar in size and mineral makeup to earth (fig.2.2).



Fig.2.2

B- The outer planets are:

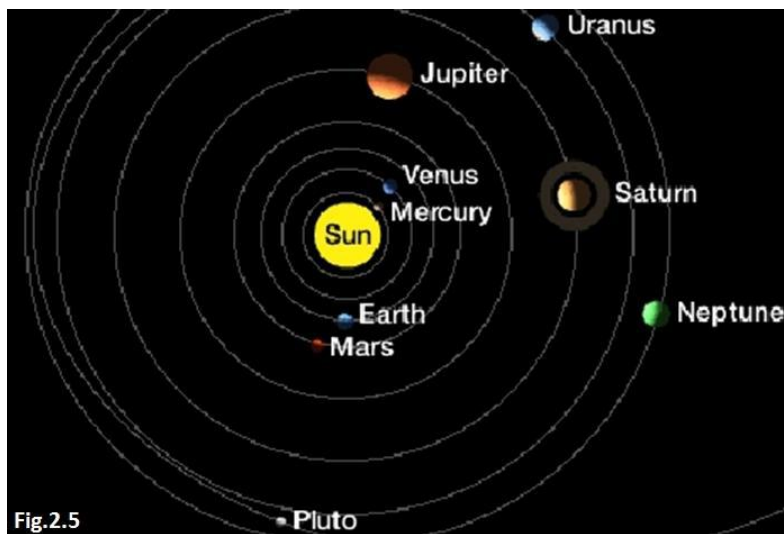
Jupiter, Saturn, Uranus and Neptune.

They are much farther from the sun and thus, They are much colder than the inner planets. (Fig. 2.3).

The outer planets are also referred to as the **Jovian planets** (Jupiter-like) or as **giants** because of their size. (Fig. 2.4).



Because small size of **Pluto** and similarity to other icy bodies found in the outer solar system, **Pluto** was demoted to **dwarf planet** status. (Fig.2.5).

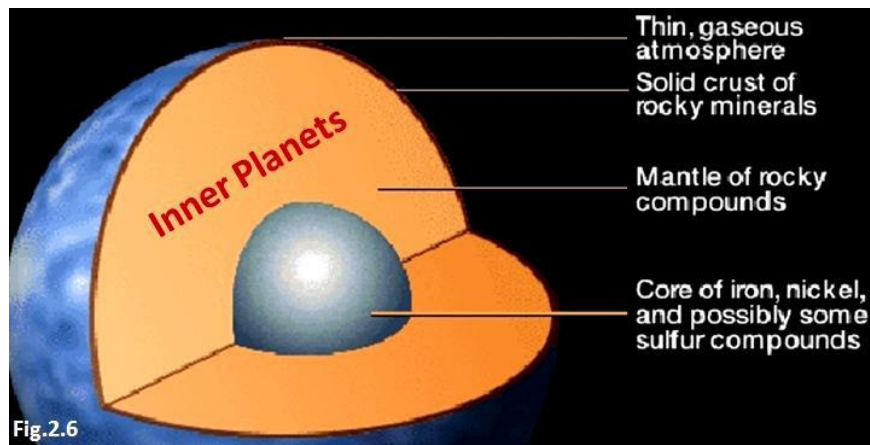


The substances that make up both the inner and outer planets are divided into three groups: Gases, Rocks and Ices based on their melting points.

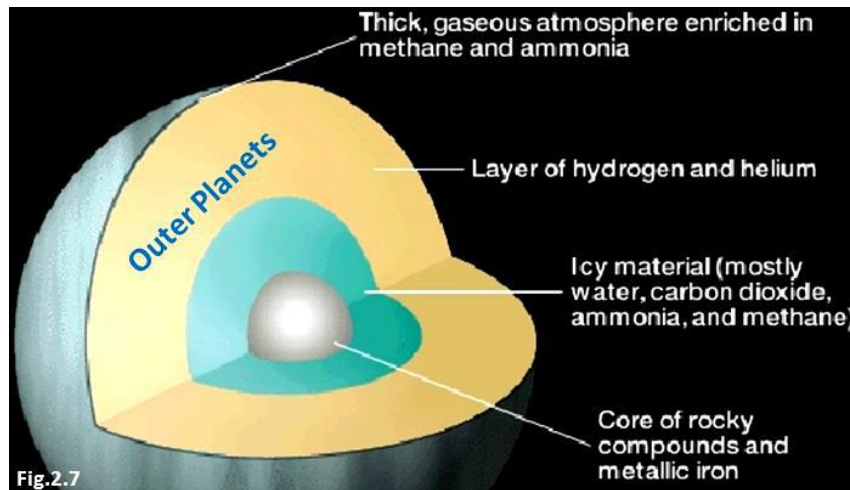
- 1- 273C°).
- 2- Rocks are principally silicate minerals and metallic iron, which have melting points exceeding 700C° .
- 3- Ices include ammonia (NH_3), methane(CH_4), carbon dioxide(CO_2), and water(H_2O).They have intermediate melting points(for example, H_2O has a melting point of (zero C°).

The inner planets: are composed of rocky crust and mantle, and metallic core made mostly of iron. Compared to the outer planets, these planets contain very small amounts of ice and gases.

(Fig. 2.6).

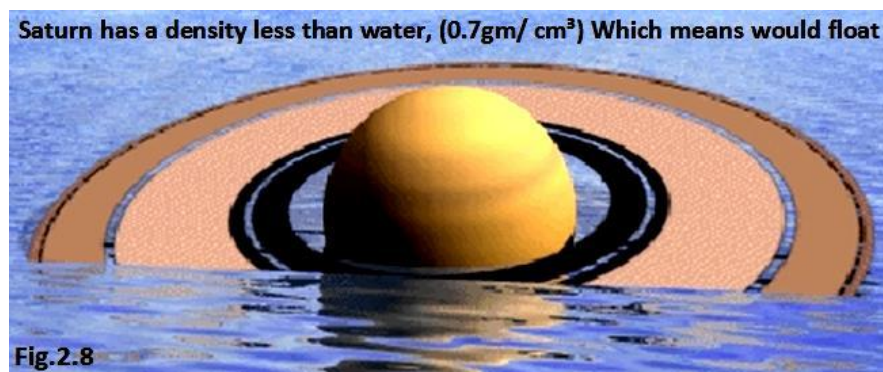


The outer planets: on the other hand contain large quantities of gases (hydrogen and helium) and ices. They also contain a small core composed of rocky material and metallic iron. (Fig. 2.7).



Because of differences in chemical makeup, the inner planets have densities that average about 5 times that of water, whereas the outer planets have densities that average less than 1.3 times of water.

(Fig.2.8) and (table.2.1)



Inner Planets الداخلية الكواكب

Average Density(g/cm³)

Outer Planets

Average Density(g/cm³)

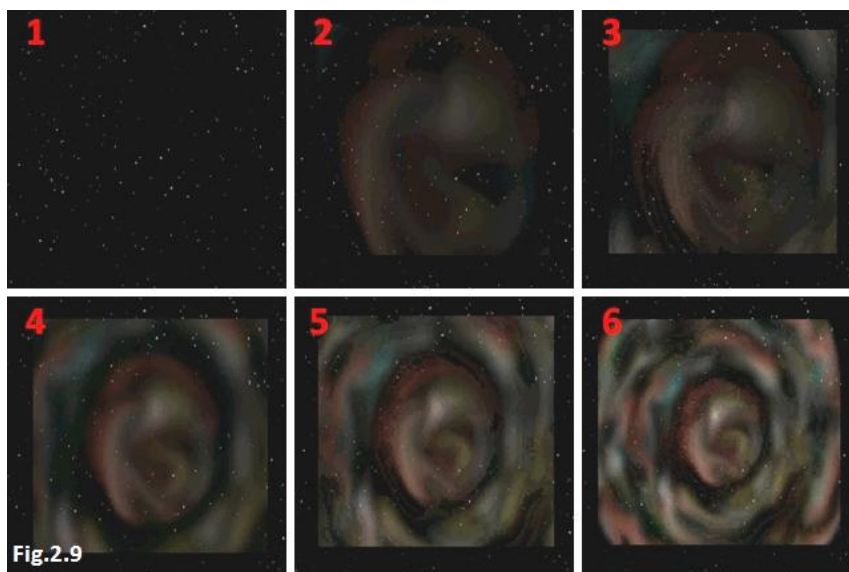
Mercury 5.4 Jupiter 1.3 Venus 5.2 **Saturn 0.7 Earth 5.5** Uranus 1.2

Mars 3.9 Neptune 1.7

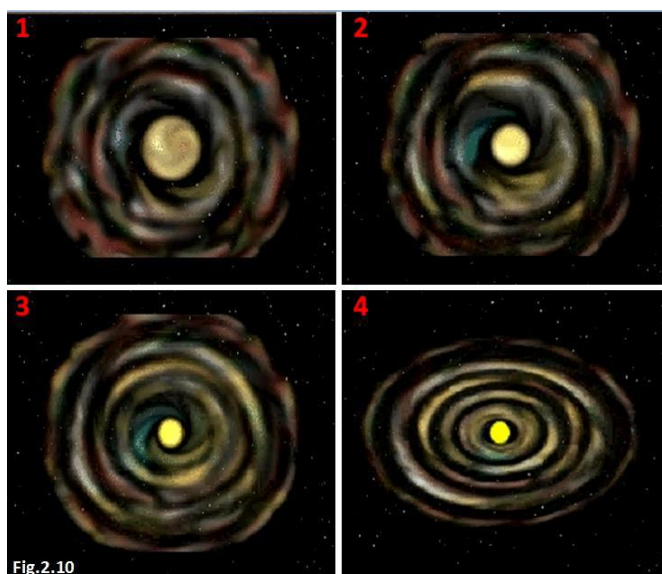
To understand why the outer planets are so much larger than the inner planets we must first examine:

2.3- how the solar system formed?

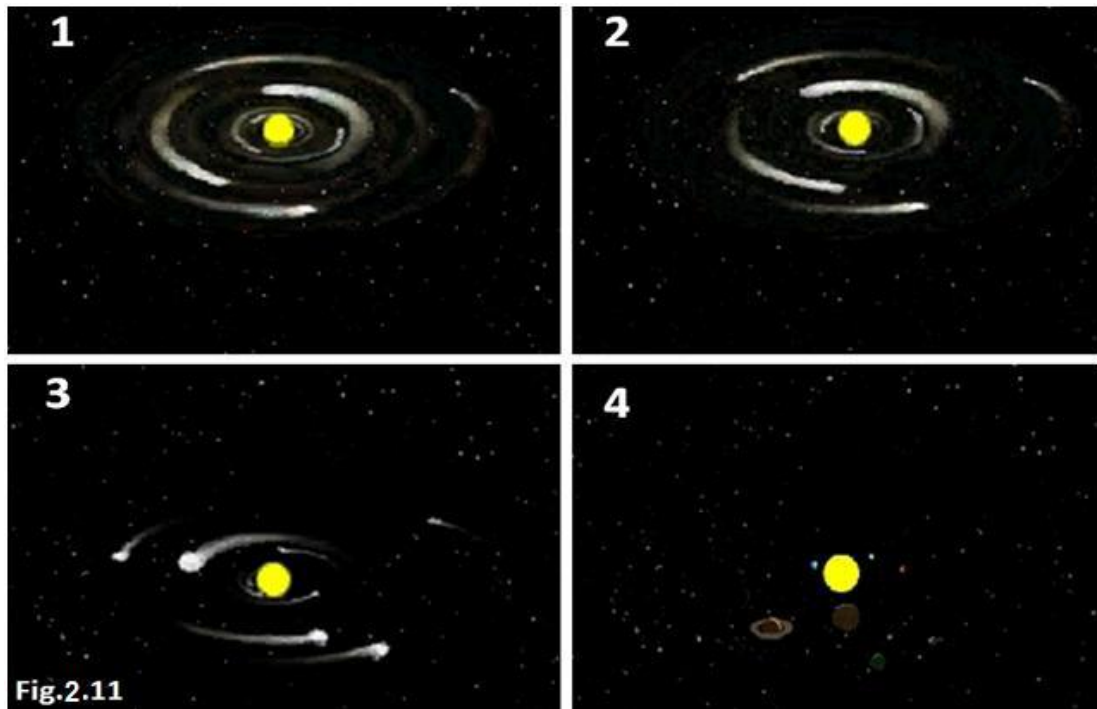
According to the (**nebular hypothesis**) the solar system formed when a huge, rotating cloud composed of minute rocky fragments and gases (mostly hydrogen and helium) began to contract. (Fig.2.9).



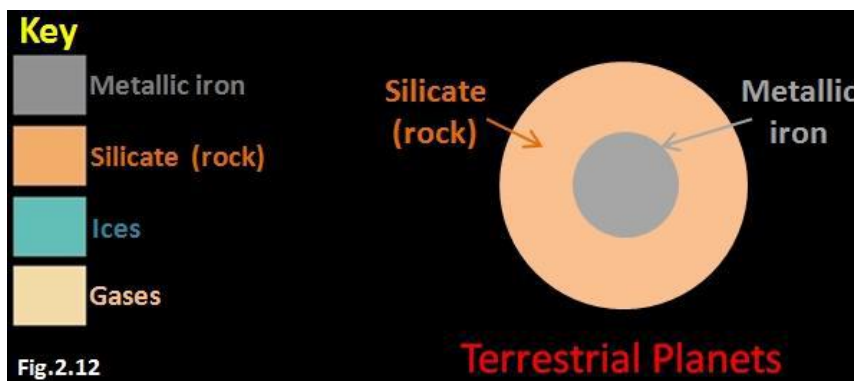
Most of the material, (over 99%) was pulled by gravity toward the center, forming the sun. rotation caused the remaining rocky fragments and gases to form a flat, rotating disk. (Fig.2.10).



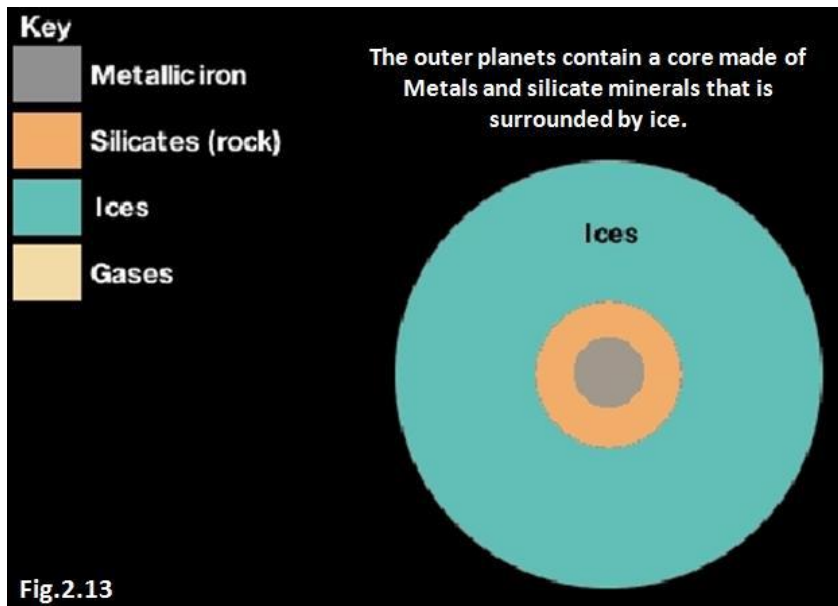
Repeated collisions caused these fragments to join together into larger asteroid - sized bodies called **planetesimals**, which accreted (grew larger) and ultimately formed the planets. (Fig.2.11).



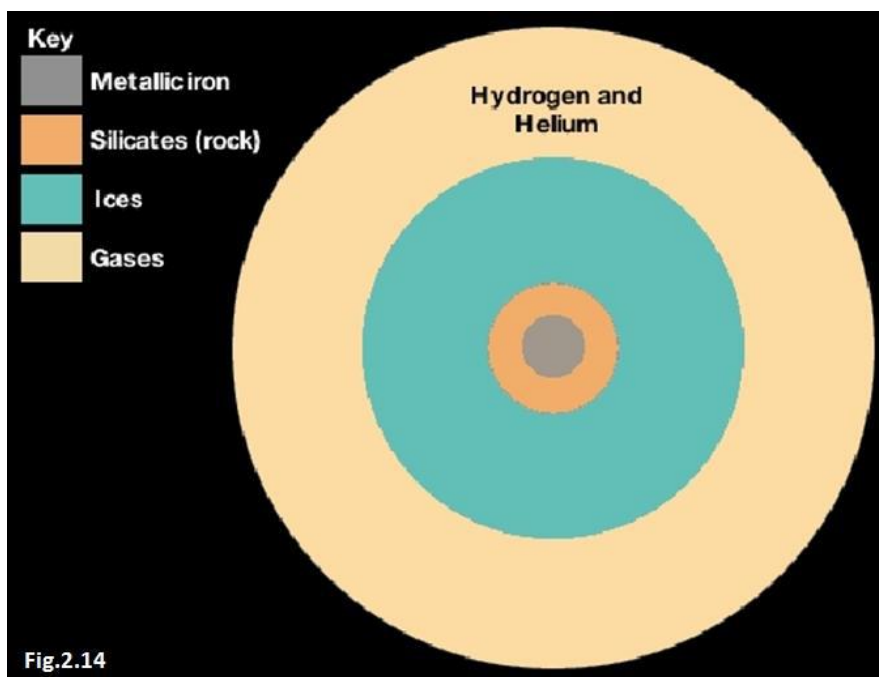
In the inner solar system, the temperatures were so high that only metals and silicate minerals could form solid grains. Thus, the earthy planets (terrestrial) grew mainly from high melting points substance. (Fig.2.12).



Because of the frigid temperatures far from the sun, the outer planets (Jupiter, Saturn, Uranus and Neptune) collected huge quantities of ices (water, Carbone dioxide, ammonia and methane) which greatly added to their sizes. (Fig.2.13).

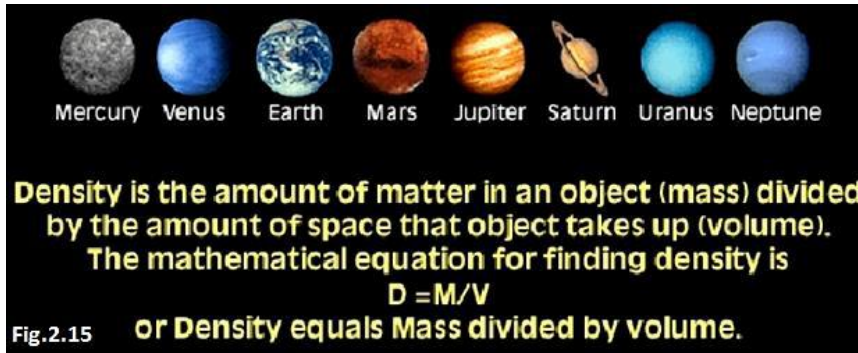


The outer planets, particularly Jupiter and Saturn, grew large enough to gravitationally attract and hold large quantities of the lightest elements.....hydrogen and helium (fig. 2.14)



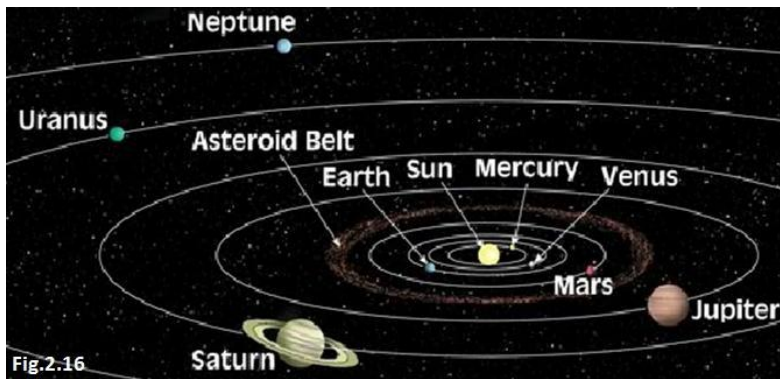
As a result, the solar system is composed of:

- **Large outer planets.**
 - **And smaller inner planets.**
- (Fig.2.15).

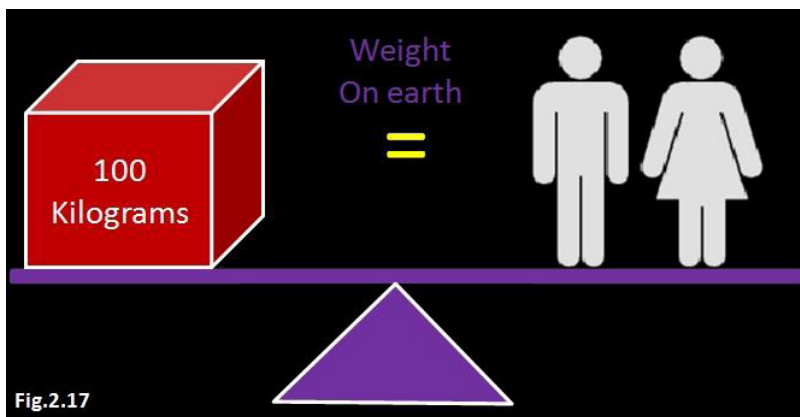


2.4-Weight and time at planets:

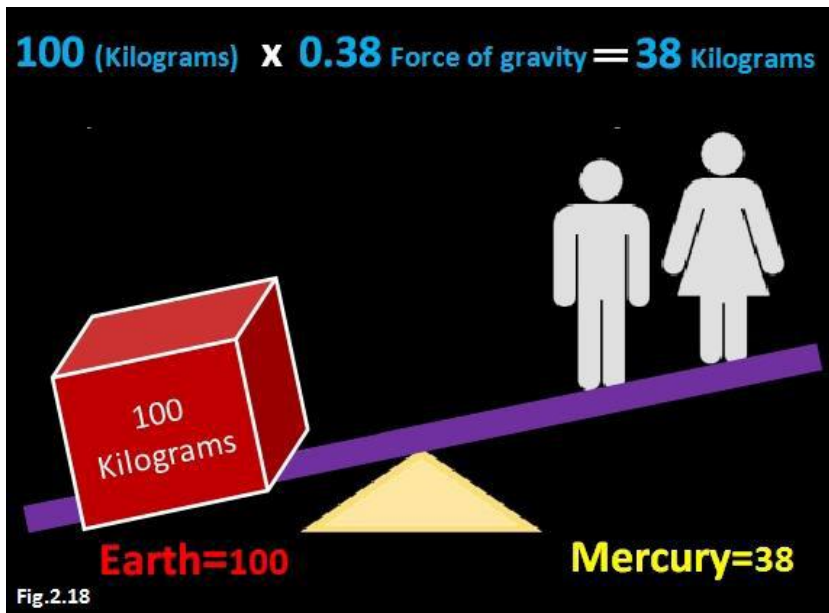
In this section you will learn how to calculate your weight and age on other planets. Further, you will be able to examine the solar distance as well as the relative size of the planets. (Fig.2.16).



To determine your weight on other planets, you simply multiply your (earth weight) by the force of gravity exerted by the planets in question requirement. (Fig.2.17)



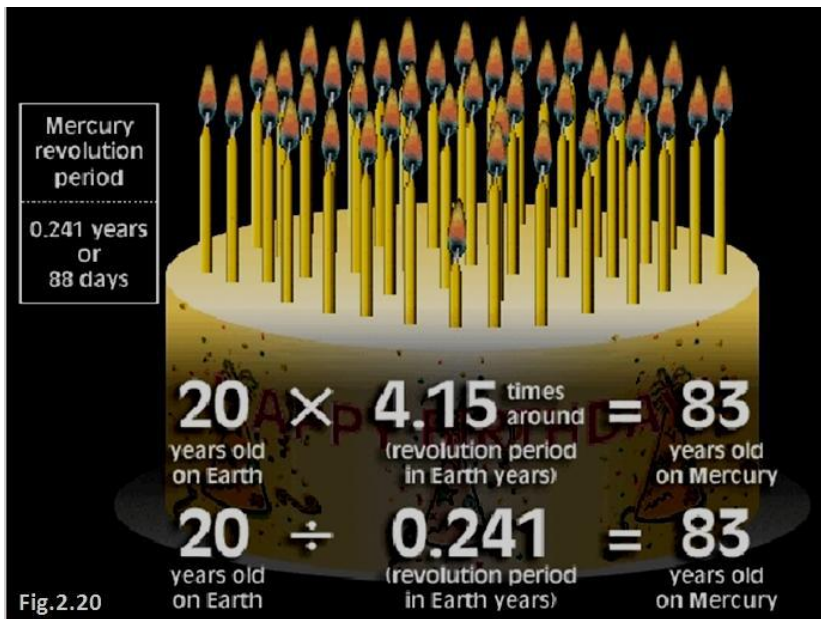
For example, if you weight 100 kg on earth, you would weight only 38 kg on mercury. This is because mercury is smaller (less massive) than earth and thus has a weaker gravitational force. (Fig.2.18).



You can calculate your age on other planets by knowing how long it takes the planets to travel around the sun. (Fig. 2.19).



For example, if you are 20 earth years old and you live on mercury, you would be 83 years old, because mercury goes around the sun 4.15 times in an earth year. (Fig.2.20).

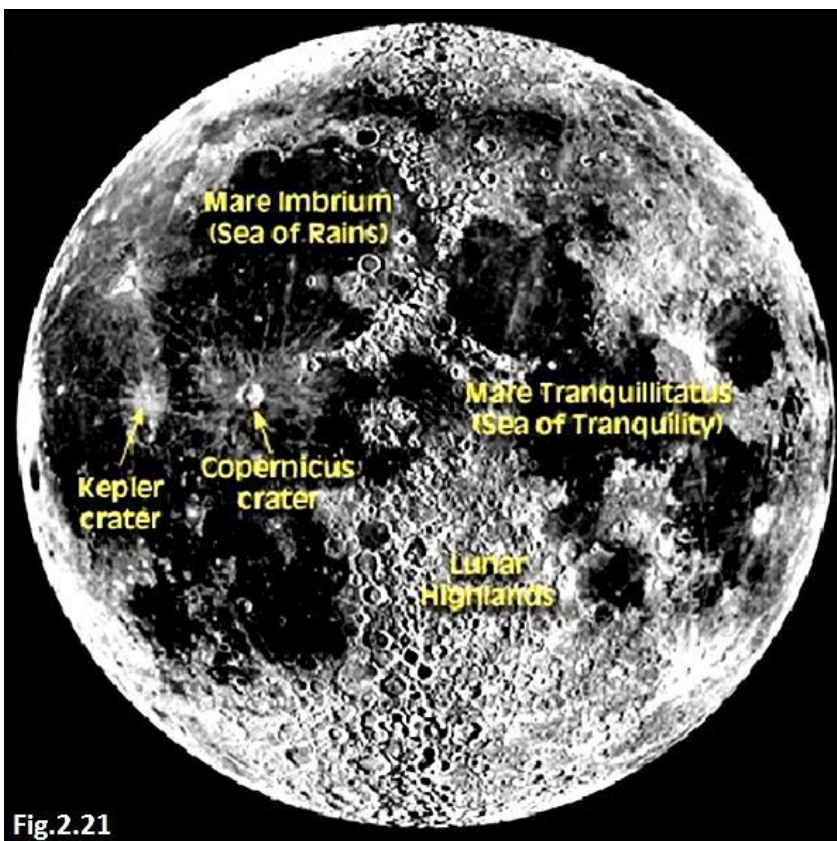


2.5- Earth's Moon:

The moon is earth's only natural satellite, and the only body in the solar system other than earth, to be studied firsthand.

The gravitational attraction on the lunar surface is one-sixth (1/6) that of earth's. Therefore, astronauts can carry their "heavy" life-support system with relative ease.

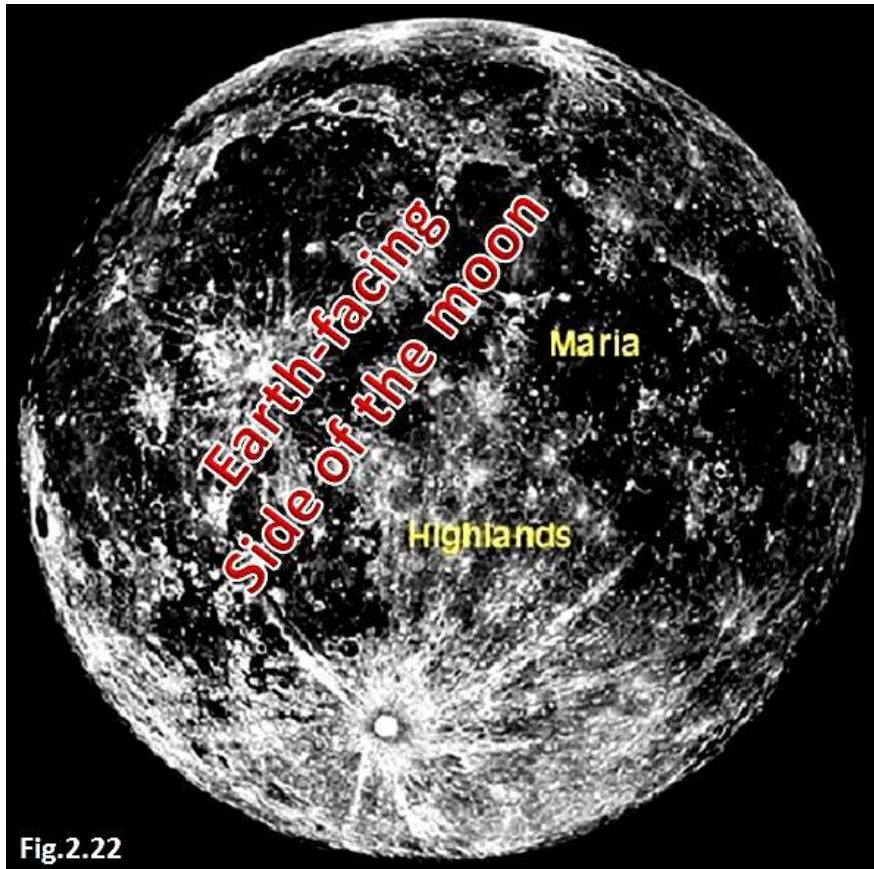
Because the moon rotated on its axis once for every revolution, the same side always faces earth. (Fig.2.21)



On the earth-facing side of the moon we can easily pick out its two major topographic regions:

A- highlands: The brighter and heavily cratered areas.

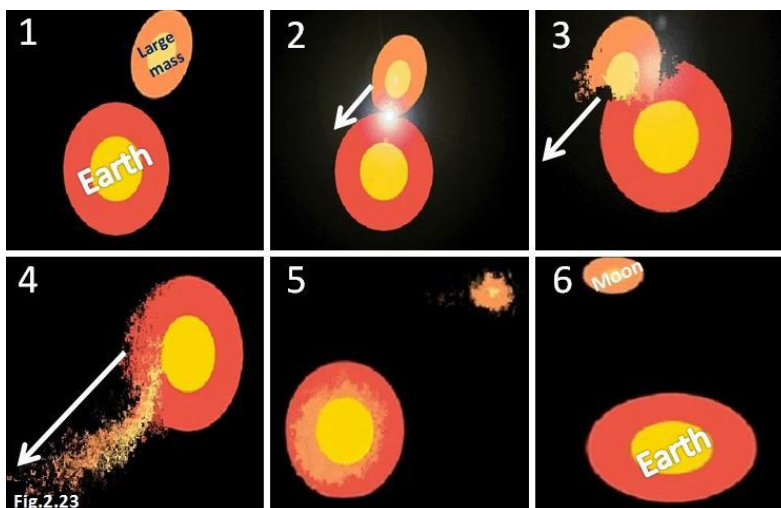
B- Maria: Dark, nearly flat regions are called (Latin for sea). (Fig. 2.22).



The most widely accepted hypothesis for the origin of the moon suggested that a large mass-sized body impacted earth. This event apparently occurred shortly after earth formed.

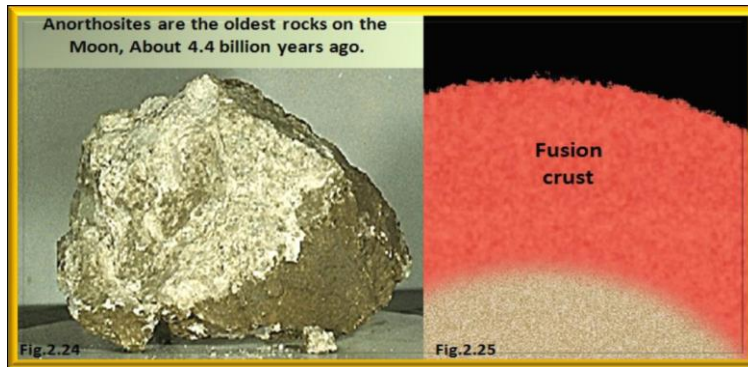
The impact would have produced immense heat and sent a huge amount of debris into orbit around earth where it coalesced to form the moon.

(Fig. 2.23).



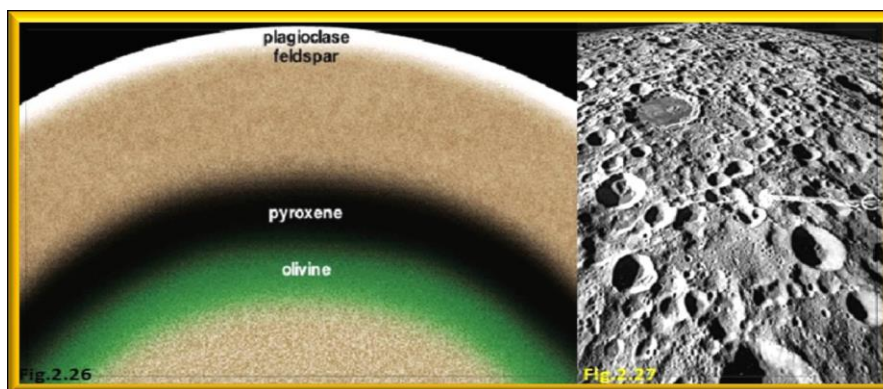
Planetary geologists were able to piece together the early history of the moon from samples of the rock **anorthosite**. In addition to being the oldest moon rocks, anorthosites are unique because they are composed almost entirely of one mineral, plagioclase (feldspar). (Fig. 2.24).

The discovery that a single mineral, plagioclase feldspar, was the major component of the moon's initial crust, led researchers to conclude that the moon's outermost layer was once molten. (Fig.2.25).



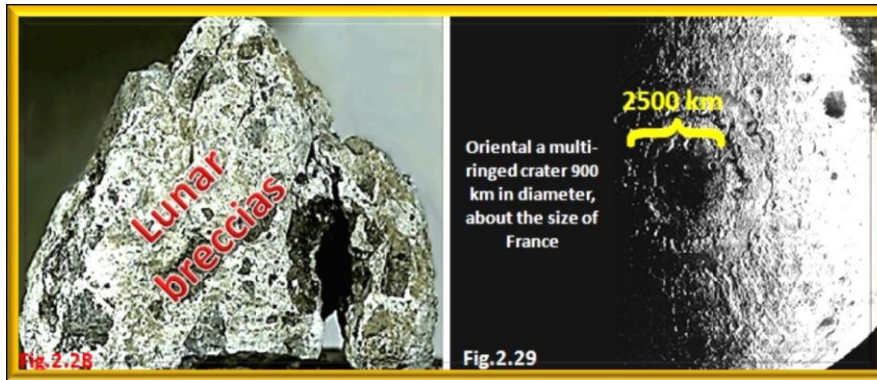
When this surrounding magma began to cool and crystallize, dense minerals such as olivine and pyroxene sank, while less dense plagioclase feldspar floated upward to form the anorthosite crust. Because the moon once had a surrounding magma, it is possible earth may have had one as well. (Fig.2.26).

Once formed, moon's crust was bombarded by debris from space for a period of several hundred million years. The craters produced during this period are visible today in the lunar highlands. (Fig. 2.27).

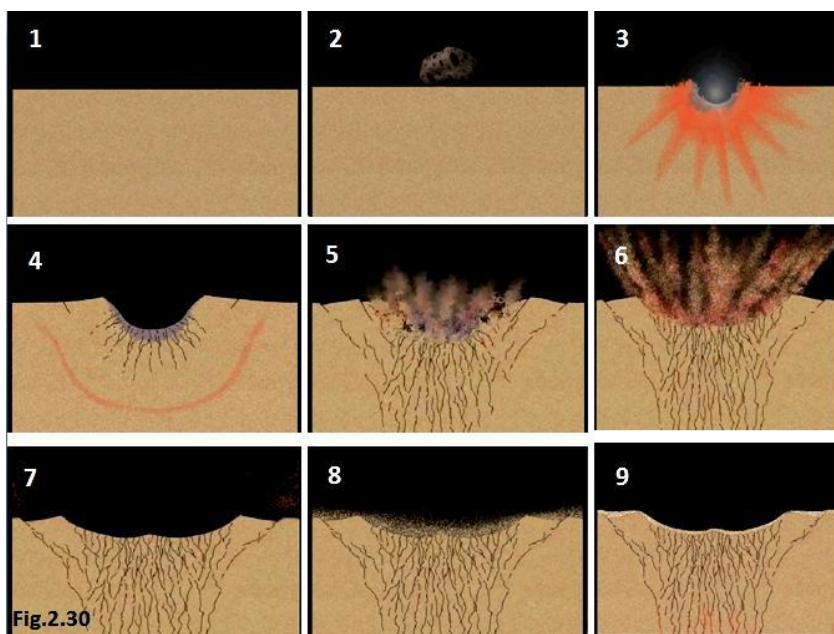


During this period of bombardment, crustal rocks were broken, melted and mixed together to form **Lunar breccias**. (Fig. 2.28).

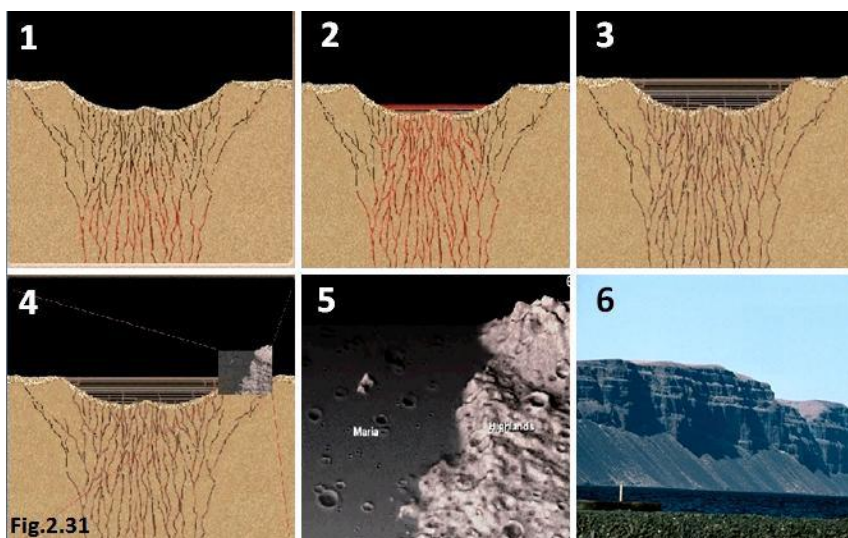
The moon was battered relentlessly until about 3.8 billion years ago. The impact made craters of all sizes including multi-ringed basins up to 2500 kilometers in diameter. (Fig.2.29).



The largest impacts produced huge craters and fracture the lunar crust sufficiently to allow magma to bleed out. (Fig.2.30).

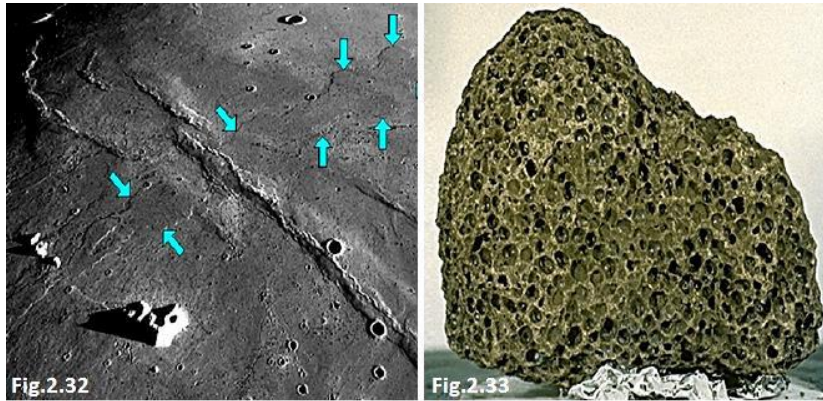


These craters were flooded with layer upon layer of very fluid lavas resembling those of the Columbia Plateau in the Pacific Northwest. (Fig.2.31).



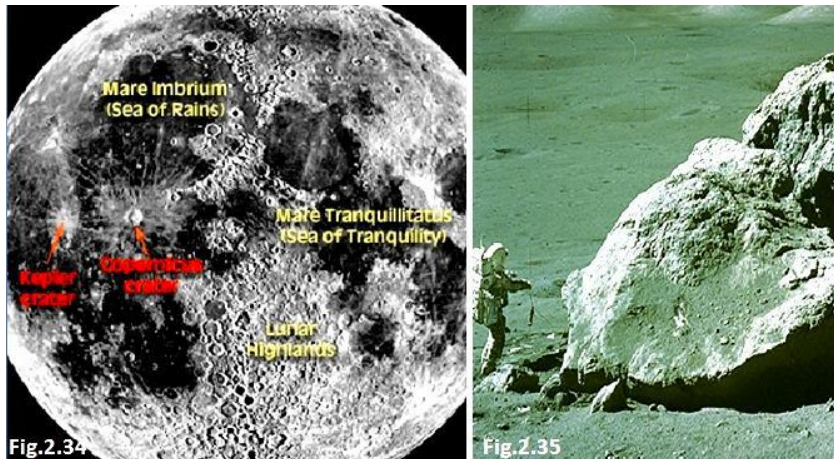
Lava intermittently flowed into these low areas for up to a billion years. The arrows point to the front of ancient lava flows on (Mare Imbrium). (Fig.2.32). Eventually, the dark, flat, and comparatively craterless regions of the moon called **Maria** were formed.

Samples brought back by the (**Apollo 15**) (Fig.2.33) mission confirmed what geologists suspected, that the Maria lavas were composed of the rock basalt. Like similar basalt flows found in the Columbia Plateau region of the northwestern United States, the Maria lavas were very fluid and traveled hundreds of kilometers before solidifying



Rayed craters are the most recently formed prominent features on the moon. Materials ejected from these "young" depressions blanket the surface of Maria and older ray less craters. (Fig.2.34).

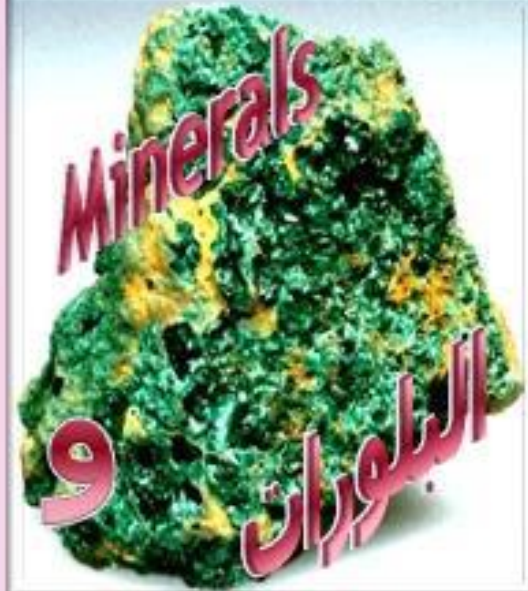
All lunar terrains are mantled with a layer of gray, unconsolidated debris, called **regolith**, derived from a few billion years of meteoric bombardment. (Fig.2.35).



- 1- Write the planets of the solar system from nearest to farthest from the sun.
- 2- Indicate the planet that has more and less number of satellites.
- 3- What are the materials that make up the solar system? Number and explained in detail.
- 4- Compare among the planets group of internal and external components of the solar array.
- 5- Put true or false to the following sentences: - Pluto can swim in the water. - Mars is the farthest planet from Earth. - Saturn is the dwarf planets. - The temperature of the outer planets is less than the inner planets. - Watch the moon face and always one in our city.
- 6- If your weight on Earth 70 kg, what your weight on Mercury if you know that the gravitational force (3.7 m / S^2).
- 7- How much is your life on Mars? If you know that the time of rotation of Mars around itself reach (687 earthy days).
- 8- What are the constituent minerals and rocks of the Moon's crust? And what is called the high and low areas in the surface of the moon?
- 9- What is the most acceptable hypothesis in the emergence of the moon?
- 10- How our solar system formed?

Chapter Three

الفصل الثالث



Crystals

- Introduction.
- Lattice.
- Crystal.
- Crystal properties.
- Crystal systems.

البلورات

- المقدمة.
- الشبكة.
- البلورة.
- خصائص البلورات.
- الأنظمة البلورية.

Minerals

- Introduction.
- Mineral groups.
- Physical properties of minerals.
- Economic use.

المعادن

- المقدمة.
- مجموعات المعادن.
- الصفات الفيزيائية للمعادن.
- الاستخدام الاقتصادي.

Crystals

3.1- Introduction:

Some of us may be surprised when they learn that the common metals such as copper, silver, aluminum and other ... As well as most of the solids are crystalline materials. Although we are accustomed to features of crystalline materials such as quartz and diamonds and salt, the faceted Clear and specific angles between the facets that may not seem to the eye while cutting metal familiar. However Body is crystalline metals, metal products, hiding in the susceptibility of metals as a result of roads and configuration. The judgment on the substance not is because of their outward appearance, but over the regularity of atoms and molecules of the arrangement League.

Crystallography dawned in 1913 with evidence of scientific based on X-ray and its potential

3.2-Lattice: Consists crystal typical of a repeat of a regular infinite in vacuum units constructivism identical, in the simplest crystals such as crystal copper or silver, for example, as well as in crystals of alkali metals, the unit reconstructive contain a single atom, and may contain the unit Constructivism in the general situation on several atoms or molecules until it reaches about a hundred atom in inorganic crystals, and to about ten thousand atom in the crystallization of proteins.

3.3- Crystal: It is a solid body, The arrangement of atoms in which the pattern of recurring.

3.4- Crystals properties: They are depending on:

1-Crystal faces: Are the surfaces that define the shape of the crystal which is mostly flat, and rarely to be convex or concave. Indicate these surfaces on a regular atomic arrangement engineering firm, which consists on the basis of the crystal material. (Fig.3.1).

2- Crystal angles:

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

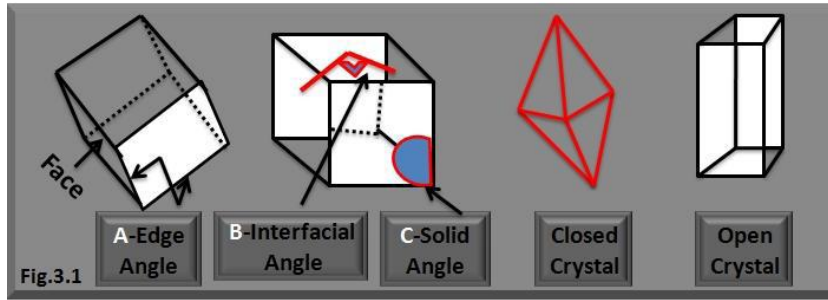
b-**Interfacial angle:** It is an angle between two faces; it can be measured by two perpendicular columns on neighbor and opposite faces.

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

3- Crystal form:

They are similar surface of the crystal consists of each type of face or two faces and at least one related to the crystal axes.

The crystal can be form of one shape of faces named (simple form) or many shapes named (compound form).



3.5- Crystal symmetry:

It is a phenomenon of the formation of a regular crystal form depending on the arrangement of atoms and ions of the constituent material in accordance with the coordination of certain natural, and show to the symmetry repetitive exchange aspects of the body as per their positions to take the crystal single-mode twice or more if they are administered in the crystal full cycle around the axis given.

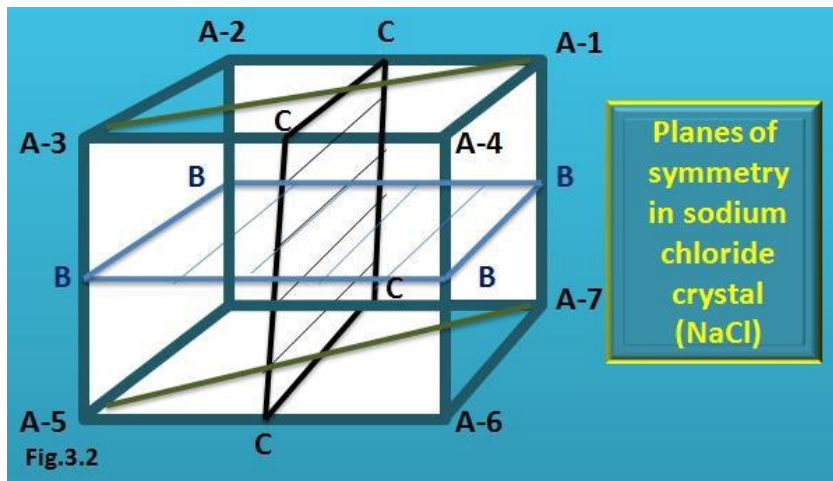
3.6- Elements of symmetry:

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

- 1- Plane of symmetry.
- 2- Axis of symmetry.
- 3- Center of symmetry.
- 4- Inversion axis of symmetry.

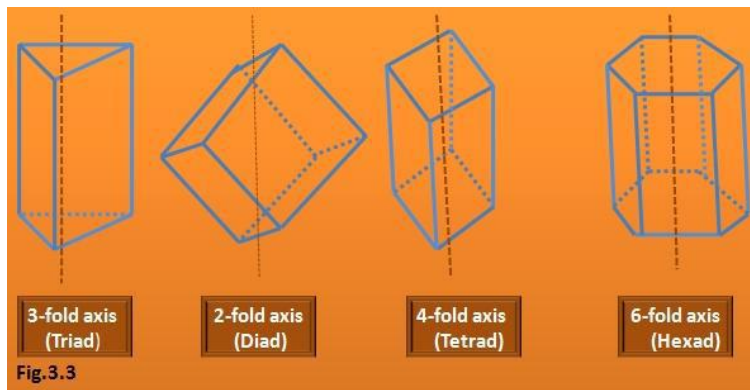
1- Plane of symmetry:

It is the plane at which the crystal is divided into two equal halves, each half a mirror image of the other. (Fig.3.2).



2- Axis of symmetry:

It is an imaginary line pass through crystal center. If the crystal is rotated around that line (360°), face, edge and any line of crystal repeat its self twice or more. (Fig.3.3).



3- 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.

4- Inversion axis of symmetry:

This element collects between rotation symmetry and Inversion through the Center of crystal. If the crystal has double inversion at rotation axis, it needs crystal rotation for (180°) firstly, and then inversion every face, edge, or surface in crystal through symmetry center until the crystal takes its situation in vacancy. This axis is called (two-fold inversion) or (2). So for (3), (4) and (6).

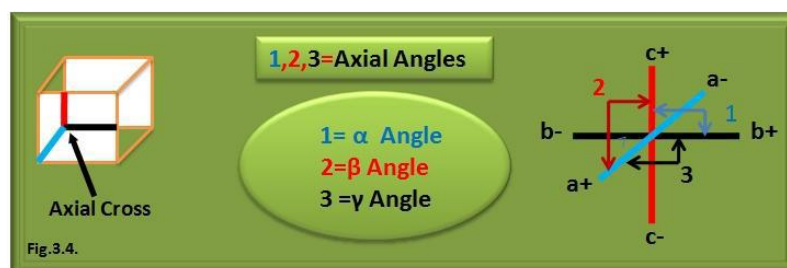
3.7- Crystallographic axes:

Imaginary lines intersect within the crystal in its traditional downstream and up to different indications described for it place the crystal facets, each face more cuts at the center or at a distance from the center, which is normally three axes: a. b. c. (Fig.3.4).

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.



3.8- Crystal Systems = (Crystallographic systems):

Denominations of the crystals were similar in terms of the lengths of its member's crystalline axes and angles between them, and each system crystalline symmetry elements of its own, and also distinctive crystalline axes.

3.9- System of the crystals:

The crystal systems are divided into two classes:

A- Depend on the axis lengths of crystal
x α β γ .

B- Depend on the elements of symmetry
grade in the crystal.

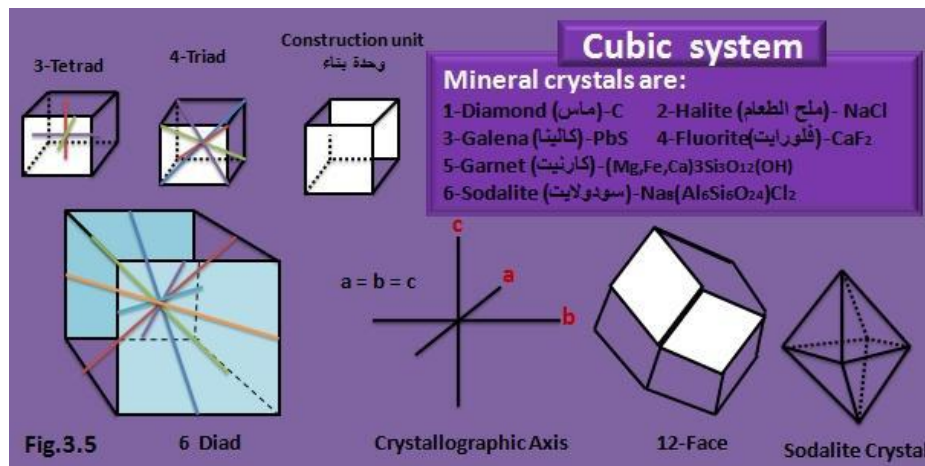
On the basis of (A and B) above, the crystal systems divided into seven systems:

- 1-Cubic system.
- 2-Tetragonal sys.
- 3-Hexagonal sys.
- 4-Trigonal sys.
- 5-Orthorhombic sys.
- 6-Monoclinic sys.
- 7-Triclinic system.
- 1- Cubic system:**

A- Crystallographic axis: 1- Three axes.
 2- Equal axes.
 3- Perpendicular axes.

B- Elements of symmetry:

- 1- Axis of Symmetry=13 axis (3.Tetrad + 4.Triad + 6.Diad).
- 1- Planes of symmetry= 9
- 3- Center of symmetry= present. (Fig.3.5).



2- Tetragonal System:

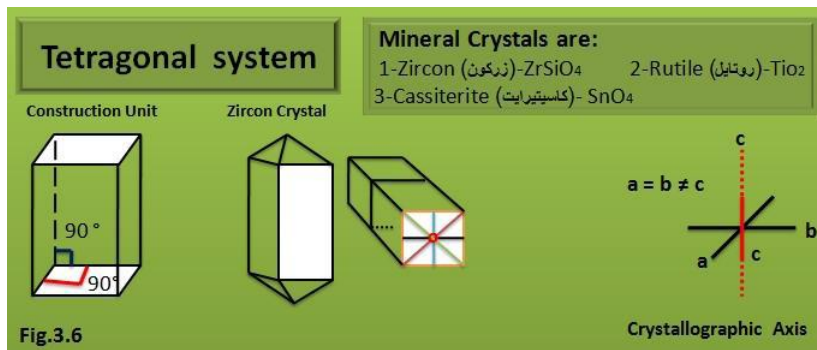
A- Crystallographic Axes:

Three axes (two are equal, perpendicular and horizontal, while the third is longer or shorter and vertical on the two equal axes).

B- Elements Symmetry:

- 1- Axis of symmetry= 5 Axis (1.Tetrad + 4. Diad).
- 2- Planes of symmetry= 5
- 3- Center of symmetry= present. (Fig.3.6).

-



3- 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).

B- Elements of symmetry:

- 1- Axes of symmetry= 7axes (1. Hexad + 6. Diad).
- 2- Plane of symmetry= 7
- 3- Center of symmetry= present. (Fig.3.7).

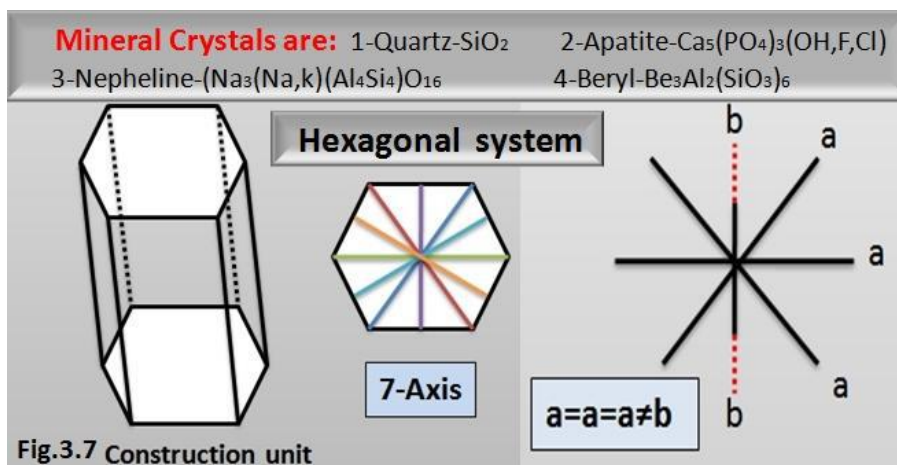
4- Trigonal system:

The Trigonal system is like hexagonal system except:

- A- One axis of symmetry (1- Triad).
- B- Non existence any horizontal planes of symmetry.

Mineral crystals (Trigonal System) are:

- 1- Calcite- CaCO_3
- 2- Corundum- Al_2O_3
- 3- Hematite- Fe_2O_3
- 4- Dolomite- $(\text{CaMg})\text{CO}_3$



5- Orthorhombic system:

A- Crystallographic axes:

- 1- Three different length axes.
- 2- The axes are perpendicular on each other.

B- Elements of symmetry:

- 1- Axes of symmetry = 3 (Diad).
 - 2- Planes of symmetry = 3
 - 3- Center of symmetry = present.
- (Fig.3.8).

A-Crystallographic Axis:-

- 1-Three different length Axis.
- 2-The Axis are perpendicular. On each other.

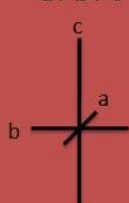
B-Elements of Symmetry:-

- 1-Axis of Symmetry = 3 (Diad).
- 2-Planes of Symmetry = 3
- 3-Center of Symmetry=available.

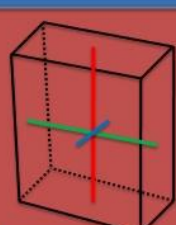
Mineral Crystals are: 1-Topaz- $\text{Al}_2(\text{SiO}_4)(\text{OH},\text{F})_2$ 2-Anhydrite- CaSO_4 3-Sulfur-S
 4-Andalusite- Al_2SiO_5 5-Olivine- $(\text{FeMg})\text{SiO}_4$ 6-Barite- BaSO_4

Orthorhombic System


$a \neq b \neq c$



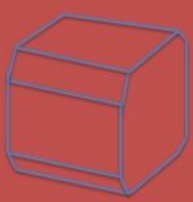
Crystallographic Axes



Construction Unit



Sulfur Crystal



Anhydrite Crystal

Fig.3.8

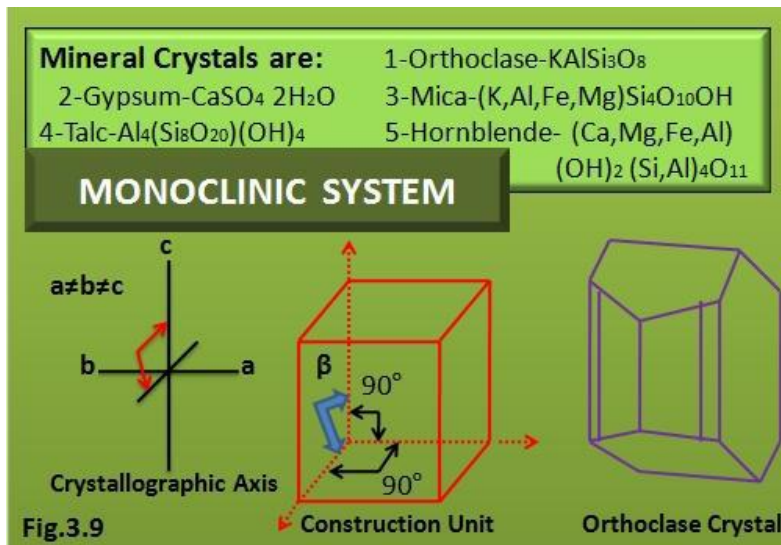
6- Monoclinic system:

A- Crystallographic axes:

- 1- Three unequal axes.
- 2- Two axes intersects (A and C) at inclined β .
Beta angle sandwiched between a and b 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
- 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. (Fig.3.9).



7- Triclinic system:

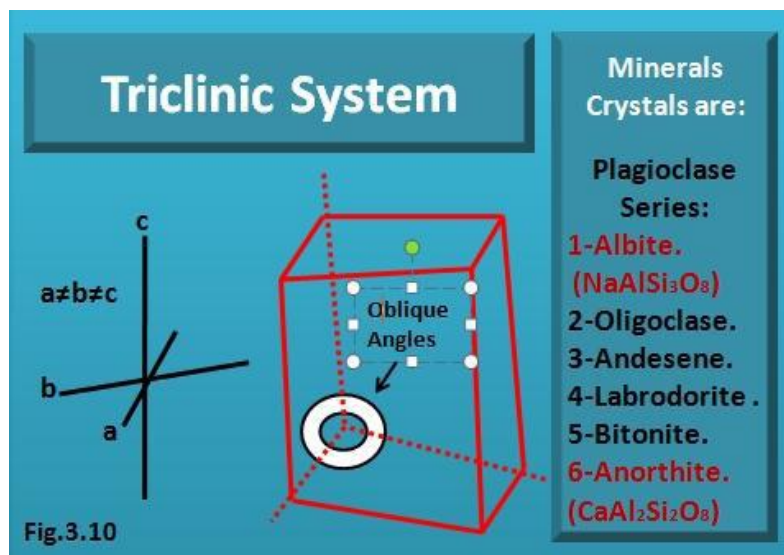
A- Crystallographic axes:

- 1- Three unequal axes.
- 2- Un-perpendicular axes.

B- Elements of Symmetry:

- 1- Axes of symmetry = absent.
- 2- Planes of symmetry = absent.

(Fig.3.10).



- 1- What is the meaning of crystal? Write the natural properties of crystals.
- 2- What is the crystal symmetry and elements of symmetry?
- 3- How many crystal systems in the earth crust minerals?
- 4- Match the correct words for the following

: A- Plagioclase

Cubic system.

B- Beryl	Tetragonal sys.
C- Diamond	Hexagonal sys.
D- Hematite	Trigonal sys.
E- Zircon	Orthorhombic sys.
F- Quartz	Monoclinic sys.
G- Anhydrite	Triclinic system.

Minerals:

3.10- Introduction:

Mineral is inorganic substance which occurs naturally, and typically has a crystalline structure whose characteristics of hardness, luster, color, cleavage, fracture, and relative density can be used to identify it. Each mineral has a characteristic chemical composition.

Earth's crust is the source for a wide variety of useful and essential minerals.

Most people know that copper is used for electrical wiring and gold is used for jewelry.

But most people are not aware that the main ingredient in cosmetics is a powdered form of the mineral talc $Mg_3Si_4O_{10}(OH)_2$ or that the mineral quartz (SiO_2) is the main ingredient in glass. (Fig.3.11).



In addition to the economic importance of rock and minerals, events such as volcanic eruptions, mountains building, and earthquakes all involve these earth materials.(Fig.3.12). 1.

1-A rock can be defined simply as an aggregate of one or more minerals. Aggregate is mixture of minerals or rock can be sorted by the mechanical means.

2-Although most rocks are composed of more than one mineral, certain minerals are found in large, impure quantities. In these instances, they are considered to be a rock.

3-It is showing limestone outcrop (composed of the mineral calcite).

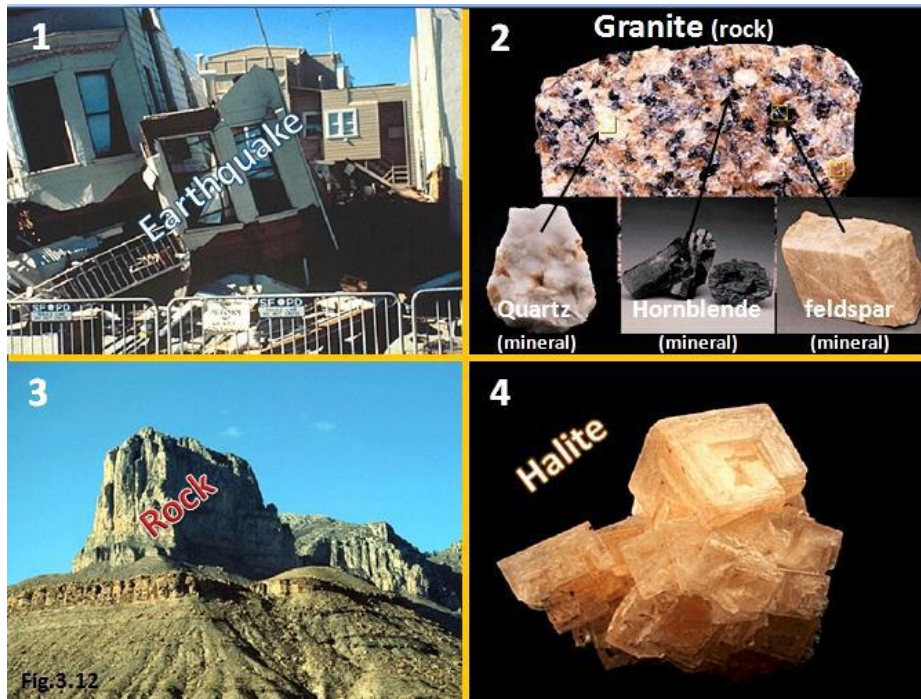
4-Nearly **4000** different minerals have been identified. No more than a **few dozen are abundant**.

Collectively, these few make up most of the rocks of earth's crust; they are classified as **rock- forming minerals**. 3.

By contrast:

Mineral:

A naturally occurring, inorganic solid with a definite chemical composition and a systematic internal structure.



3.11- Mineral Groups:

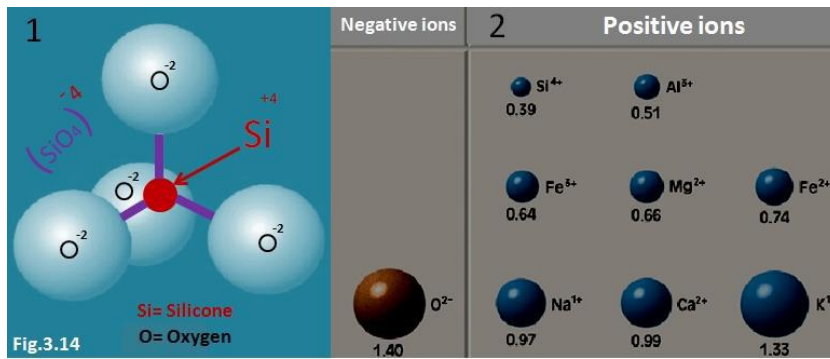
1- Silicate group:

The most common group of rock forming minerals is the silicates. (Fig.3.13).

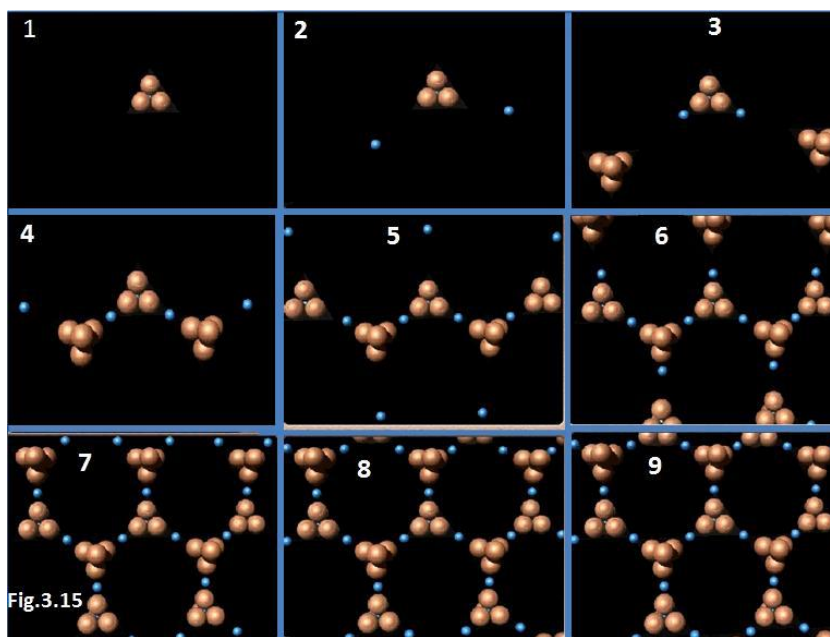


All silicates have the same fundamental building block, the silicon-oxygen tetrahedron.

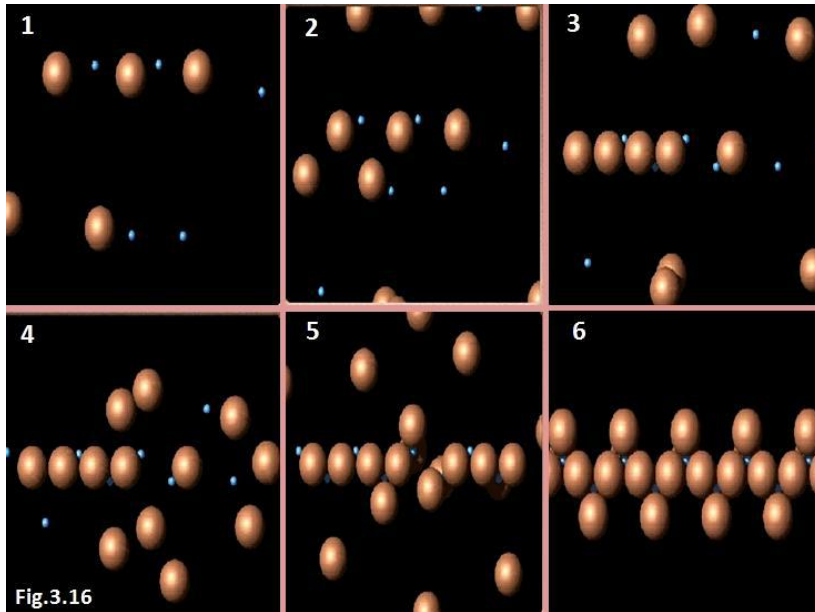
The silicon- oxygen tetrahedron is not a compound. Rather, it is a complex ion with a charge of $(- 4)$. (Fig.3.14.). 1. In nature, tetrahedral form neutral chemical compound (minerals) through the addition of positively charged ions. 2.



In this way, chemically stable structure is produced, consisting of individual tetrahedral linked together by positively charged ions. (Fig. 3.15).



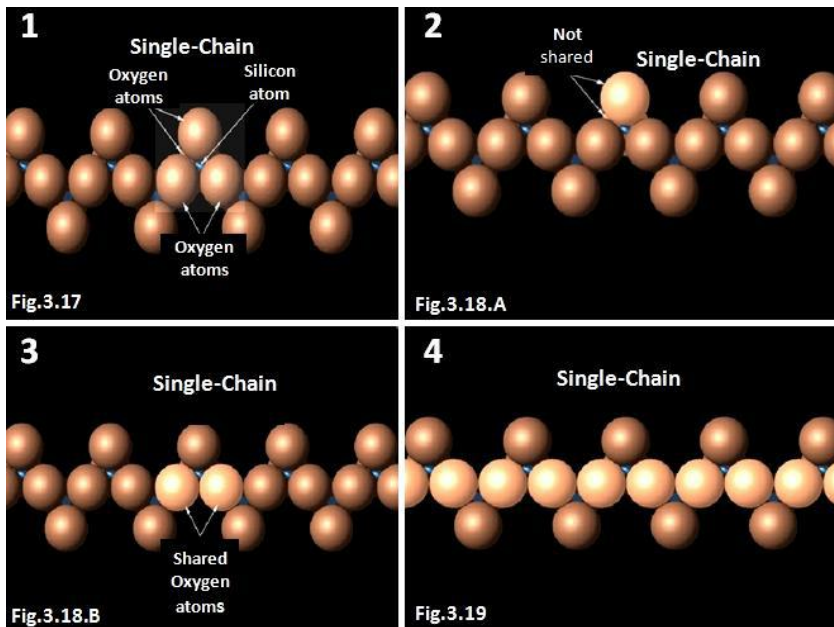
In addition, the tetrahedron may form a variety of structures by sharing the **oxygen atoms** between silicon atoms in adjacent tetrahedrons. (Fig.3.16).



Notice that in this chain structure, each silicon atom is completely surrounded by four larger oxygen atoms. (Fig.3.17). 1.

Also notice that two of the four oxygen atoms are not shared atoms, whereas the other two are jointed to other silicon in this manner. (Fig.3.18.). 2 & 3.

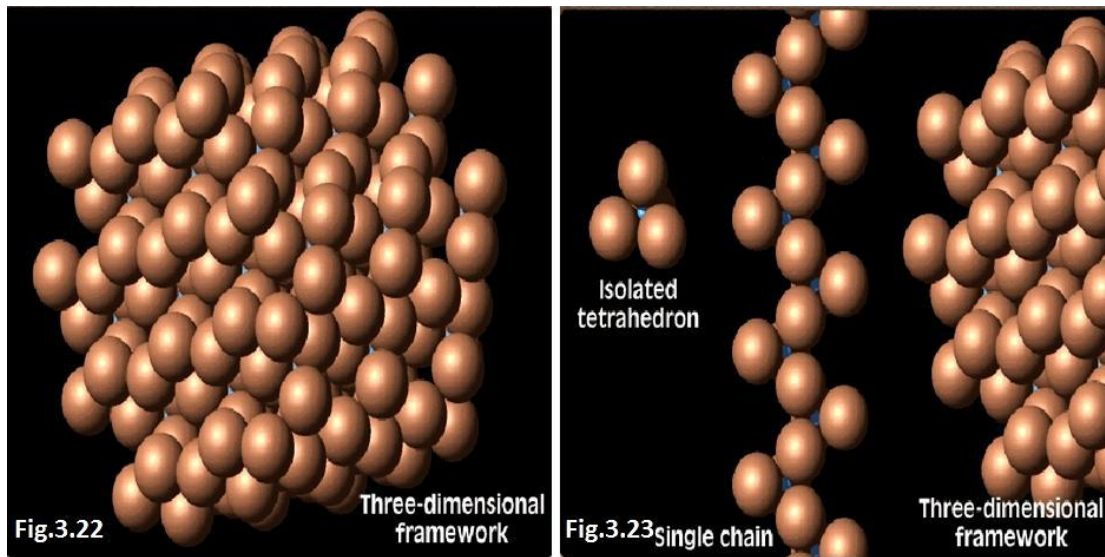
It is the linkage across shared oxygen atoms that joint the tetrahedral into a chain structure. (Fig. 3.19). 4.



Other silicate structure exists. These include **double chains**. (Fig.3.20). 1. 2. 3. **Sheet structures** (Fig. 3.21). 1. 2. 3.

Complex **three-dimensional frameworks** (Fig.3.22).

By now we may have noticed that the ratio of silicon atoms to oxygen atoms differs in each silicate structure. (Fig.3.23).

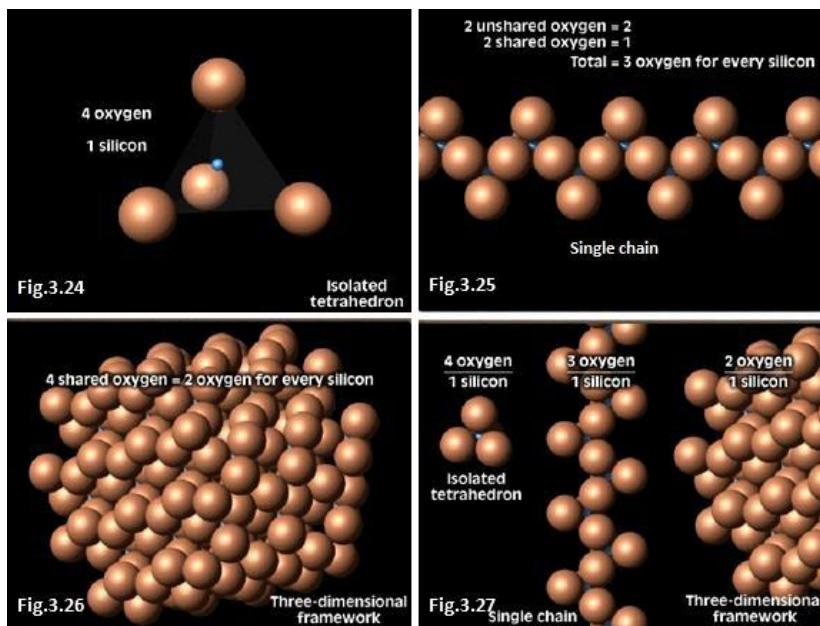


Minerals composed of isolated **tetrahedrons** contain 1 silicon atom for every 4 oxygen atoms like Olivine. (Fig.3.24).

Whereas in the **single chain**, the silicon-to oxygen ratio is 1 to 3 like Augite (An important member of the pyroxene group of silicate minerals. $(Ca(Mg,Fe)Si_2O_6)$). (Fig.3.25).

While in the **three- dimensional** framework, the silicon to oxygen ratio is 1 to 2 like Quartz (Fig.3.26).

Whenever more oxygen atoms are shared, the percentage of silicone in the minerals increases. (Fig.3.27).



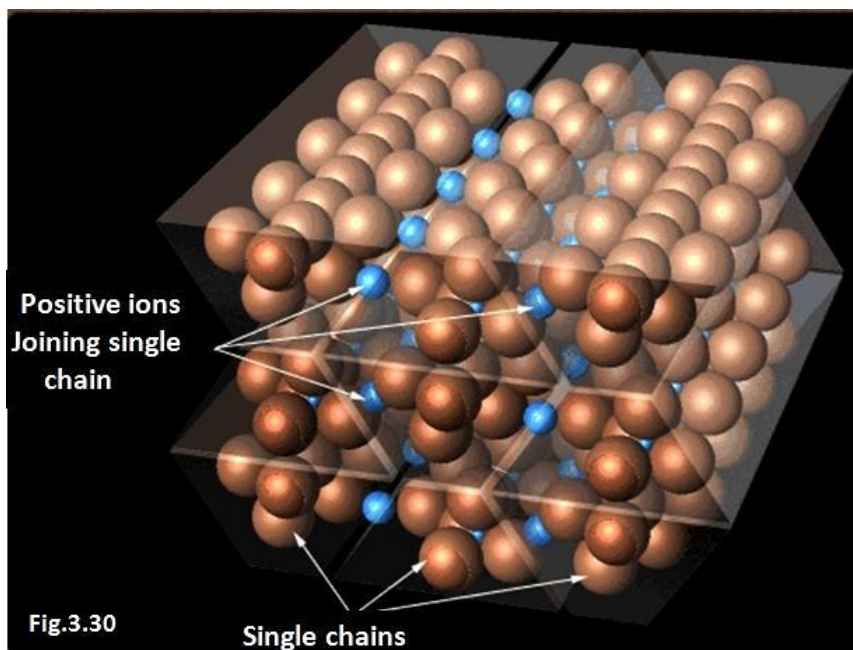
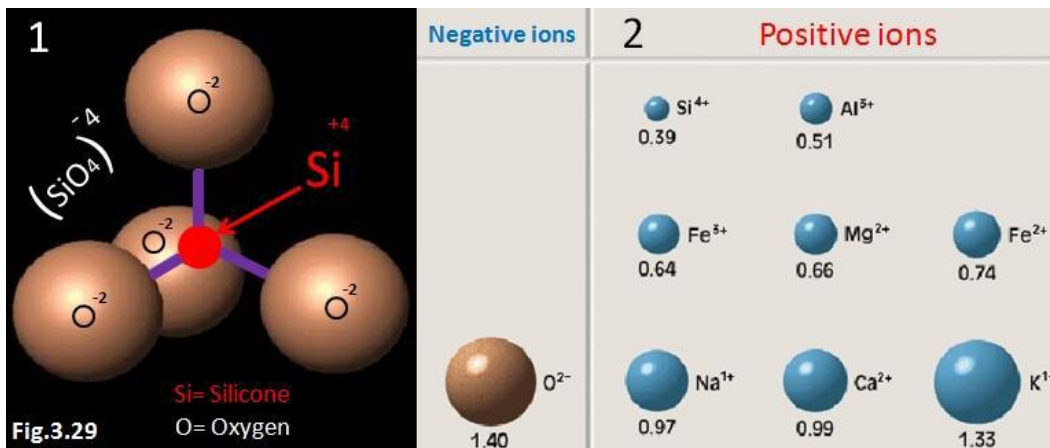
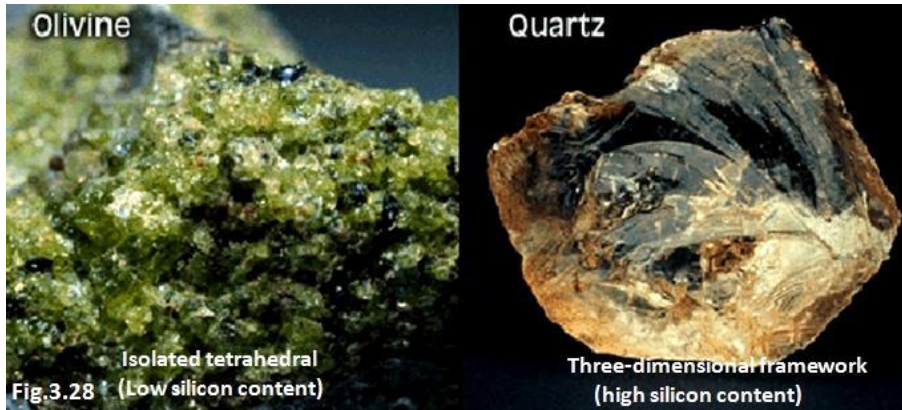
Silicate minerals are described as having "high" or "low" silicon content based on the ratio of silicon to oxygen. This difference in silicon content is important, as we will see when consider igneous rocks. (Fig.3.28).

Like the silicon- oxygen tetrahedron, most other silicate structures are not neutral chemical compounds. (Fig.3.29).1

They are all neutralized by the inclusion of positively charged metallic ions (Fig.3.29).2 that bind them together into a variety of crystalline configurations.

(Fig.3.30).

(Fig.3.30).



The major groups of silicate minerals and common examples are shown below:

Because the silicon-oxygen bonds are strong, silicate minerals tend to cleave or break between the silicon-oxygen structures rather than across them. (Fig.3.31).

For example, the micas have a sheet structure and thus tend to cleave into flat plates. (Fig.3.32).

Quartz, which has equally strong silicon-oxygen bonds in all directions, has no cleavage, but **fractures** instead. (Fig.3.33).

The silicates are generally divided into **two major groups** on the basis of their **chemical makeup**. (Fig.3.34).

Non ferromagnesian silicate (light).

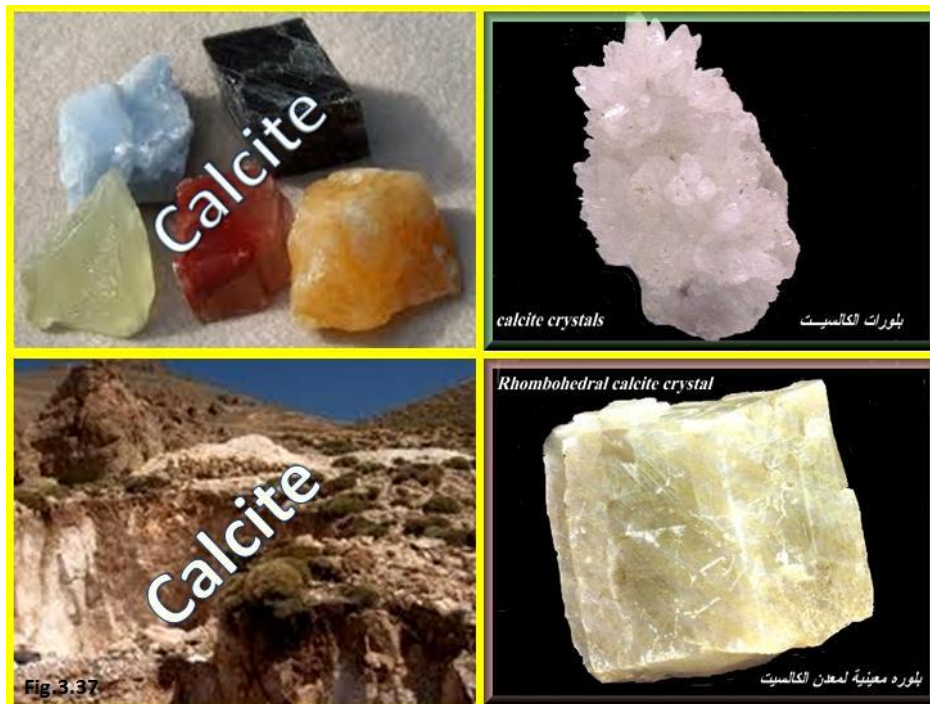
The ferromagnesian silicates (dark) are minerals in which ions of iron (Iron = Ferro) and/or magnesium join their silicates structures (Fig.3.35).

Because of their iron content, ferromagnesian silicates are darker in color (Fig.3.35) and have higher specific gravity than the **non ferromagnesian silicates (light)** (Fig.3.36).

2- Carbonate group:

Other important rock forming minerals groups include the **carbonates**.

Calcite CaCO_3 (Fig.3.37) and dolomite $(\text{CaMg}) \text{CO}_3$ (Fig.3.37). They are commonly found in the **sedimentary rocks** limestone and dolostone (dolomite)





3- Sulphate and Halides groups:



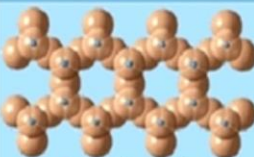
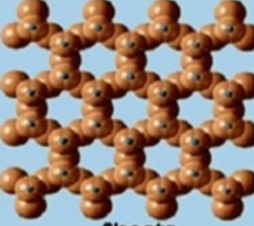
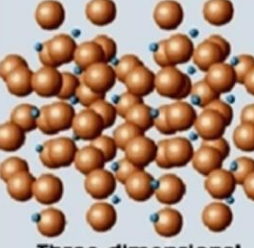
Three other non silicate minerals frequently found in sedimentary rocks are:

1-**gypsum** $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (Fig.3.39). 1.

2-**Halite** (NaCl). 2.

3-**fluorite** (CaF_2). 3.

Gypsum and halite are found in thick layers, which are the last vestiges of ancient seas that have long since evaporated.

Mineral		Idealized Formula	Cleavage	Silicate Structure
Olivine		$(\text{Mg,Fe})_2\text{SiO}_4$	None	Single tetrahedron 
Pyroxene Group (Augite)		$(\text{Mg,Fe})\text{SiO}_3$	Two Planes at right angle	Single chains 
Amphibole Group (Hornblende)		$\text{Ca}_2(\text{Fe,Mg})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$	Two Planes at 60° and 120°	Double chains 
Micas	Biotite	$\text{K}(\text{Mg,Fe})_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$	One Plane	Sheets 
	Muscovite	$\text{KA}_2(\text{AlSi}_3\text{O}_{10}) (\text{OH})_2$		
Feldspars	Ortho-Class	KAISi_3O_8	Two Planes at 90°	Three-dimensional networks (expanded view) 
	Plageo-Class	$(\text{Ca,Na})\text{AlSi}_3\text{O}_8$		
Quartz		SiO_2	None	

4- Oxides group:

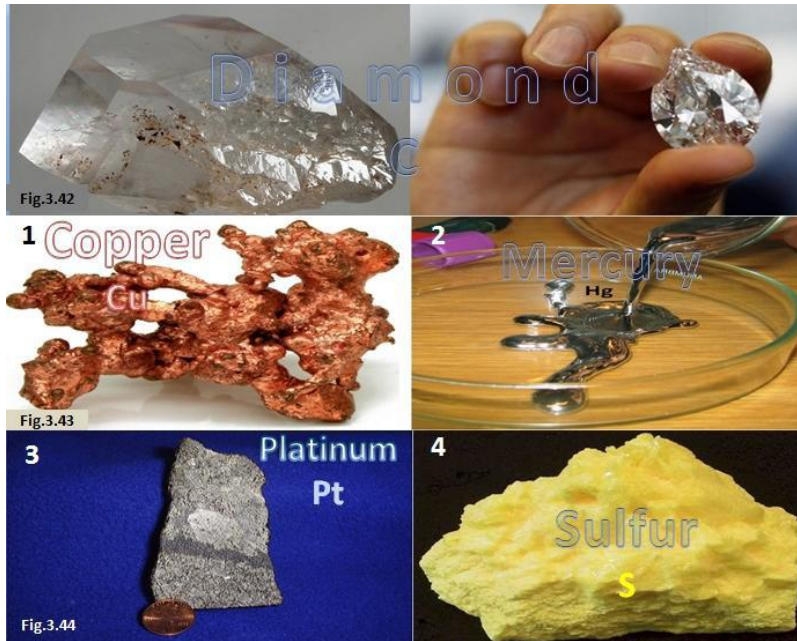
Although scarce when compared to the silicates, other mineral groups are important economically. These include the oxides like Magnetite Fe_3O_4 . (Fig.3.40).

5- Sulfides group:

Bornite Cu_5FeS_4 is the ore of the copper. (Fig.3.41).

6- Native element:

Any element found in earth crust naturally, unattached in the form of Ore mineral Like native **diamond C** which is used as gemstone and abrasive (Fig.3.42) ..., **copper Cu**, and **mercury Hg** (Fig.3.43.). 1 and 2. ... A **Platinum Pt** and **Sulfur** (Fig.3.44). 3 and 4.



3.12- Physical properties of Minerals:

Every mineral has an orderly arrangement of atoms and a definite chemical composition which gives it a unique set of physical properties.

1- Crystal form:

It is the external expression of a mineral's orderly internal arrangement of atoms like Pyrite (FeS_2) of cubic system and quartz (SiO_2) of hexagonal crystals with pyramidal-shaped ends. (Fig.3.45).

2- Luster:

It is the appearance or quality of light reflects from the surface of mineral.

A- Pyrite (FeS_2) ... Metallic luster. (Fig.3.46).1.

B- Fluorite (CaF_2) ... non metallic luster. 2.

C- Chalk (CaCO_3 -Very fine pure grains) ... Non metallic earthy luster. 3.

D- Quartz (SiO_2) ... non metallic glassy Luster. 4.

E- Bornite (Cu_5FeS_4 -Ore of copper) ... sub Metallic luster. 5.

F- Muscovite ($\text{K}_2\text{Al}_4(\text{Si}_3\text{AlO}_{10})_2(\text{OH},\text{F})_4$) ... Non metallic pearly luster. 6.

3- Color:

It is surely the most obvious characteristic of a mineral. (Fig.3.47).

Color is not always useful diagnostic property. For example, slight impurities in the mineral quartz (SiO_2) give it a variety of colors. (Fig.3.48).

4- Streak:

It is the color of a mineral in it's powdered form and is obtained by rubbing a mineral across a piece of unglazed porcelain called **streak plate**. (Fig.3.49). 1.

Although the color of a mineral may vary from sample to sample, the streak usually does not vary. 2.



Fig.3.49

5- Hardness:

It is a measure of the resistance of a mineral to abrasion or scratching.

Mohs' scale (scientist) of hardness illustrated a relative scale for the softest and hardest minerals as below:

Mohs Scale for Hardness.			مقياس موس للصلابة.
<p>1 Talc</p> <p>Human skin</p>	$Mg_3Si_4O_{10}(OH)_2$ <p>Construction Unit</p>	$KAlSi_3O_8$ <p>Construction Unit</p>	<p>6 Orthoclase</p> <p>Window glass</p>
<p>2 Gypsum</p> <p>Finger nail</p>	$CaSO_4 \cdot 2(H_2O)$ <p>Construction Unit</p>	SiO_2 <p>Construction unit</p>	<p>7 Quartz</p> <p>Steel file</p>
<p>3 Calcite</p>	$CaCO_3$ <p>Construction unit</p>	$Al_2(SiO_4)(F,OH)_2$ <p>Construction unit</p>	<p>8 Topaz</p>
<p>4 Fluorite</p>	CaF_2 <p>Construction n unit</p>	Al_2O_3 <p>Construction unit</p>	<p>9 Corundum</p>
<p>5 Apatite</p> <p>Kitchen Knife</p>	$Ca_5(PO_3)_4(OH,Cl)$ <p>Construction unit.</p>	<p>Construction n unit</p>	<p>10 Diamond</p>

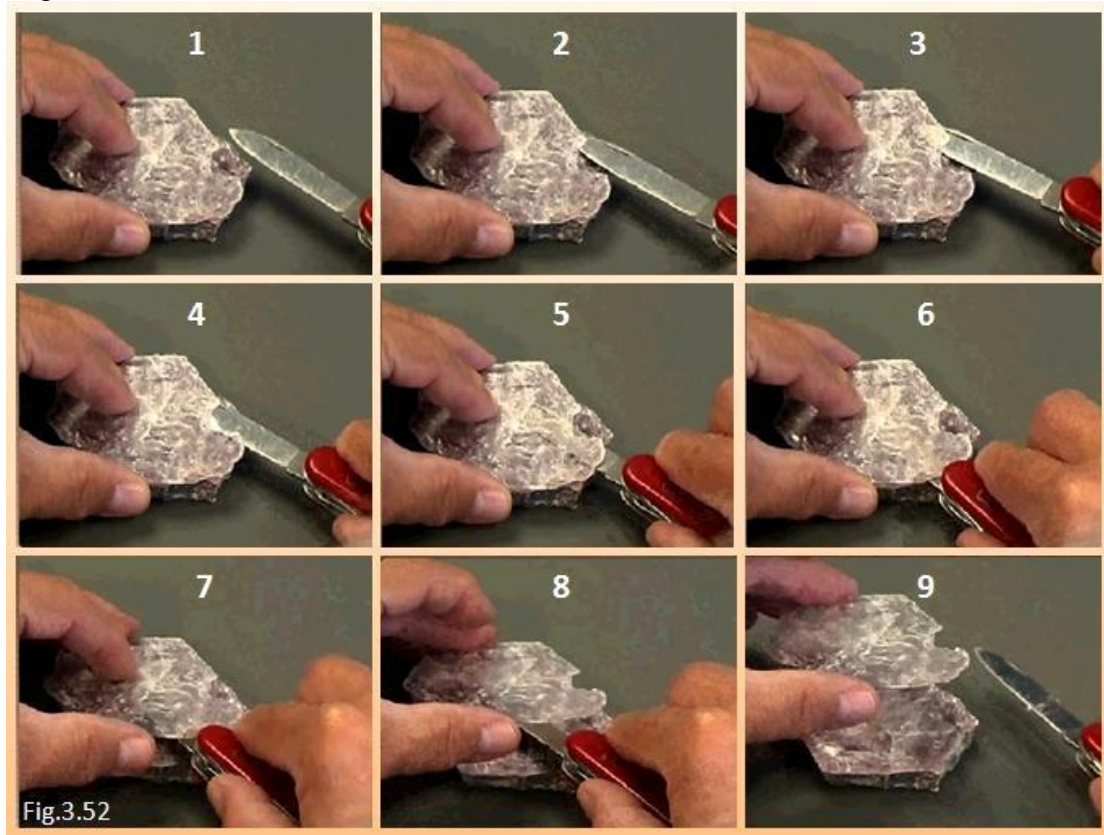
6- Cleavage:

It is the tendency of mineral to break along planes of weak bonding. (Fig.3.50).

The simplest type of cleavage is exhibited by the mica. (Fig.3.51). 1.

Because micas have weak chemical bonds in

The sample of muscovite below illustrates mineral that exhibit one plane of cleavage. (Fig.3.52).



The mineral feldspar (The most important group of rock-forming silicate minerals), including the alkali feldspars KAlSi_3O_8 to $\text{NaAlSi}_3\text{O}_8$ (K-feldspar to albite) and the plagioclase feldspars $\text{NaAlSi}_3\text{O}_8$ to $\text{CaAl}_2\text{Si}_2\text{O}_8$ (albite to anorthite), has two cleavage directions. (Fig.3.53).

When minerals break evenly in more than one direction, cleavage is described by the number of x F .3.54). 1...A which they meet like Halite mineral (NaCl). 2.

Calcite (CaCO_3) is a mineral whose cleavage angle is 75 degrees. (Fig.3.55). 1. While hornblende includes hastingsite $\text{Ca}_2(\text{Mg}_4\text{Al})[\text{Si}_7\text{AlO}_{22}](\text{OH},\text{F})_2$, tschermakite $\text{Ca}_2(\text{Mg}_3\text{Al}_2)[\text{Si}_6\text{Al}_2\text{O}_{22}](\text{OH},\text{F})_2$, edenite $\text{NaCa}_2\text{Mg}_5[\text{Si}_7\text{AlO}_{22}](\text{OH},\text{F})_2$, and pargasite $\text{NaCa}_2(\text{Mg}_4\text{Al})[\text{Si}_6\text{Al}_2\text{O}_{22}](\text{OH},\text{F})_2$; has 2 cleavage angles, one at 60 degrees and one at 120 degrees. 2.

7- Fractures:

It is important not to confuse cleavage with crystal form. Remember, crystal form is the external expression of a mineral's orderly arrangement of atoms. Whereas, cleavage is the tendency of minerals to break along planes of weakness.

All minerals have crystal form, but some minerals lack cleavage.

Minerals that do not exhibit cleavage when broken are said **fracture**, like Malachite $\text{Cu}_2\text{CO}_3(\text{OH})_2$ mineral. (Fig.3.56). 1.

Three kinds of fractures are:

- a- Irregular fracture (Bornite Cu_5FeS). 2.
- b- Conchoidal fracture (resemble broken glass). (Quartz SiO_2). 3.
- c- Fibrous fracture. (Serpentine) $Mg_6[Si_4O_{10}](OH)_8$. 4.

7- Specific gravity:

It is a number representing the ratio of the weight of mineral to the weight of an equal volume of water at 4 centigrade.

For example: The specific gravity of quartz is (2.7) galena (7.5) and gold (20).

Most common minerals have a specific gravity of between (2.5 – 3).

9- Other properties:

Other properties can be used to identify some minerals. (Fig.3.57).

For example: halite ($NaCl$) is ordinary table salt. It can be identified with your tongue.

1.

And talc ($Mg_3Si_4O_{10}(OH)_2$) feels soapy. 2.

Some varieties of magnetite (Mg_3O_4) are natural magnets. 3.

And certain minerals will effervesce (fizz) when hydrochloric acid is added Calcite $CaCO_3$. 4.

3.13-Economic use.

Economic minerals include a wide range of minerals which are used in various fields, among them groups of native elements, oxides, sulfides, halides, carbonates, sulfates, phosphates and hydroxides in addition to silicates as shown below.

Group	Member	Formula	Economic use
Native elements العناصر الحرة	Gold	Au	Jewelry, Electronics
	Copper	Cu	Electronics
	Diamond	C	Abrasive Gemstone
	Sulfur	S	Sulfur drags, Chemical
	Graphite	C	Pencil lead, Dry lubricant
	Silver	Ag	Jewelry, Photography
	Platinum	Pt	Catalyst
Oxides الأكاسيد	Hematite	Fe_2O_3	Ore of iron
	Magnetite	Fe_3O_4	Ore of iron
	Corundum	Al_2O_3	Gemstone, Abrasive
	Chromite	$FeCr_2O_4$	Ore of chromium
Sulfides الكبريتيدات	Galena	PbS	Ore of lead
	Sphalerite	ZnS	Ore of zinc
	Pyrite	FeS	Fool's gold
	Chalcopyrite	$CuFeS_2$	Ore of copper
	Bornite	Cu_5FeS_4	Ore of copper
	Cinnabar	HgS	Ore of mercury
Halides الهاليدات	Halite	NaCl	Common salt
	Fluorite	CaF_2	Use in steel making
	Sylvite	KCl	Fertilizer
Carbonate الكربونات	Calcite	$CaCO_3$	Portland cement
	Dolomite	$CaMg(CO_3)_2$	Portland cement
	Aragonite	$CaCO_3$	Portland cement
Sulfates الكبريتات	Gypsum	$CaSO_4 \cdot 2H_2O$	Plaster
	Anhydrite	$CaSO_4$	Plaster
	Barite	$BaSO_4$	Drilling mud
Phosphates الفوسفات	Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$	Fertilizers
	Turquoise	$CuAl_6(PO_4)_4(OH)_3 \cdot 4H_2O$	Gemstone
Hydroxide الهيدروكسيدات	Limonite	$FeO(OH) \cdot nH_2O$	Ore of iron, pigments
	Bauxite	$Al(OH)_3 \cdot nH_2O$	Ore of aluminum
Silicates السيليكات	Silicate minerals make up about 92 percentage of earth's crust		

- 1- Which of these mineral properties may be of minimal value in identifying the mineral quartz? a- luster. b- hardness. c- color. d- crystal form.
- 2- The ratio of silicon atoms to oxygen atoms in the same methods in each of the various silicate structures. a- true. b- false.
- 3- Which of these silicate minerals exhibits a sheet structure? a- quartz. b- muscovite. c- olivine. d- feldspar.
- 4- Which of these following is NOT a property used to identify minerals? a- hardness. b- streak. c- texture. d- crystal form.
- 5- The most common group of rock-forming minerals is the -----, a- oxides. b- silicates. c- carbonates. d- sulfides.
- 6- When minerals break evenly in more than direction, cleavage is described by the number of planes exhibited and the angles at which they meet. a- true. b- false.
- 7- Most rocks are aggregates of minerals. a- true. b- false.
- 8- A cubic centimeter of quartz and gold Weight 2.7 and about 20 grams respectively. This indicates that -----, a- Gold has a much higher specific gravity than quartz.
- 7- b- gold is much harder than quartz. c- gold is elastic than quartz. d- gold has a greater luster than quartz.
- 8- All ferromagnesian minerals contain one or both of these elements: a- iron, magnesium. b- magnesium, potassium. c- potassium, sodium. d- sodium, silicon.
- 10- The two major groups of silicate minerals are the ferromagnesian silicate and non ferromagnesian silicates. a- true. b- false.
- 11- All silicate minerals contain which of the following two elements? a- iron, magnesium. b- iron, silicon. c- silicon, oxygen. d- magnesium, silicon.
- 12- Which of these mineral properties may be of minimal value in identifying the mineral quartz? a- luster. b- hardness. c- color. d- crystal form.
- 13- All the minerals have a crystal form. a- true. b- false.
- 14- Which one of the following sets of two terms described how a mineral responds to mechanical impact? a- luster, hardness. b- hardness, cleavage. c- cleavage, fracture. d- fracture, crystal form.
- 15- The silicon - oxygen tetrahedron is a complex ion. a- true. b- false.

Chapter four: Rock cycle

الفصل الرابع: دورة الصخور

-Kinds of rocks.

1-Igneous rocks.

- Introduction to igneous rocks.
- Texture of igneous rocks.
- Composition of igneous rocks.
- Naming of igneous rocks.

2-Sedimentary rocks.

- Introduction to igneous rocks.
- Types of sedimentary rocks.
- Sedimentary environment.

3-Metamorphic rocks.

- Introduction to metamorphic rocks.
- Agents of metamorphism.
- Texture and mineralogical changes.

-أنواع الصخور.

١-الصخور النارية.

- مقدمة الصخور النارية.
- نسيج الصخور النارية.
- تركيب الصخور النارية.
- تسمية الصخور النارية.

٢-الصخور الرسوبية.

- مقدمة الصخور الرسوبية.
- أنواع الصخور الرسوبية.
- البيئات الرسوبية.

٣-الصخور المتحولة.

- مقدمة الصخور المتحولة.
- عوامل التحول.
- التغيرات النسيجية والمعدنية.

Rocks cycle:

The rock cycle is one means of viewing many of the interrelation in geology. The rock cycle shows the origin of the three c ck ... ff geologic processes transform one rock type into another.

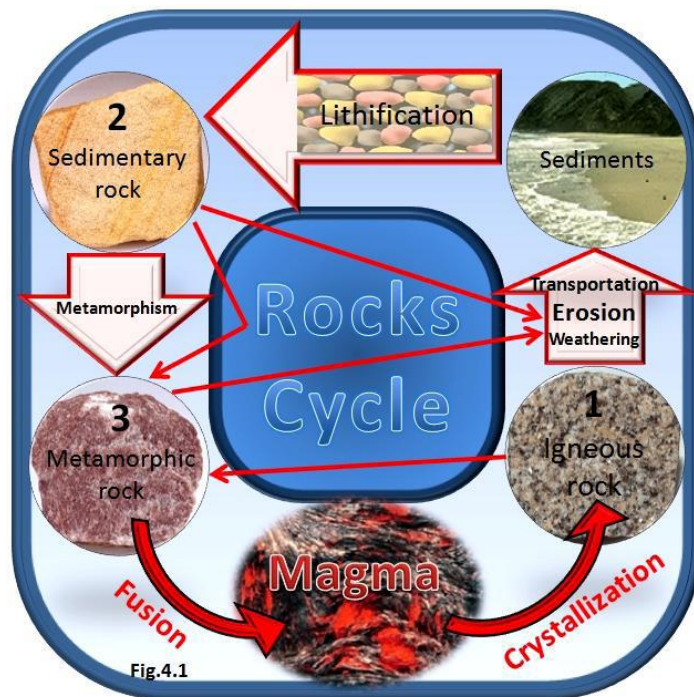
Kinds of rocks:

There are three kinds of rocks are present in the earth crust. (Fig.4.1).

1- Igneous rocks.

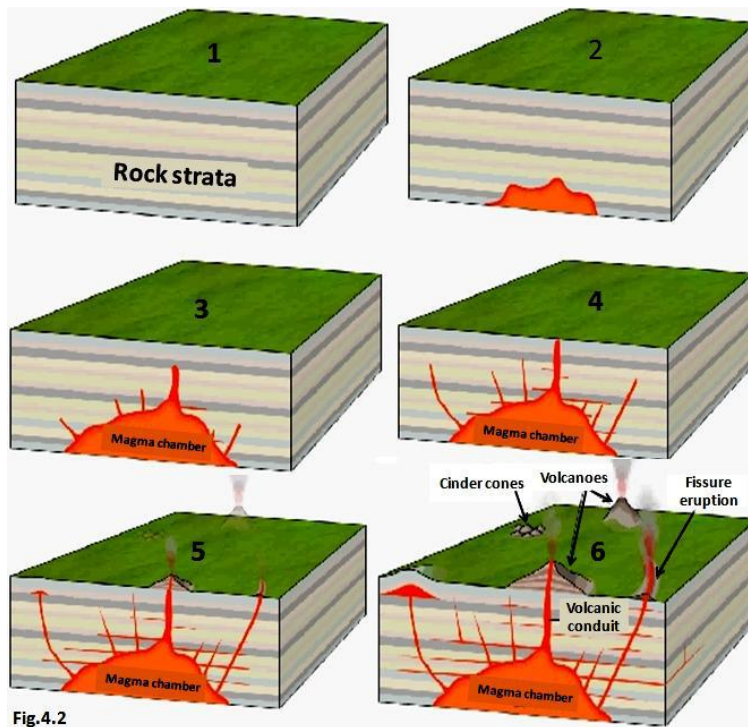
2- Sedimentary rocks.

9- Metamorphic rocks.



4.1- Igneous rocks:

- 1- **Igneous rocks** originated when molten material called **magma** cools and solidifies. (Fig.4.2).



2- Fig.4.2

This process, called **crystallization**, may occur E' f c . . . O f c (Fig.4.3).

When igneous rocks are exposed at the surface, they will undergo **weathering**, a process which slowly disintegrated and decomposes rocks. (Fig.4.4).

The rock fragments are picking up and transported by **erosion agents** (Fig.4.5)., such as:

- a- Running water. 1.
- b- Glaciers. 2.
- c- Winds. 3.
- d- Waves. 4.

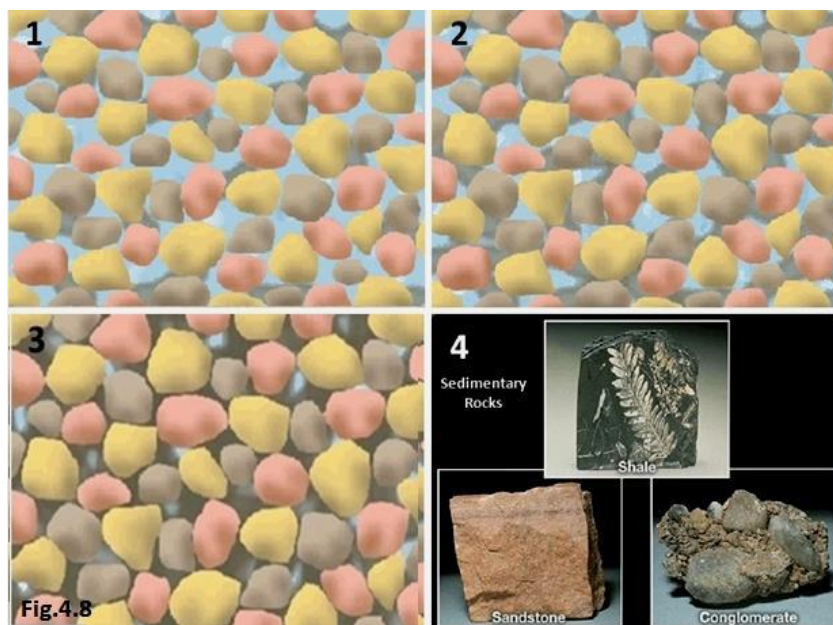
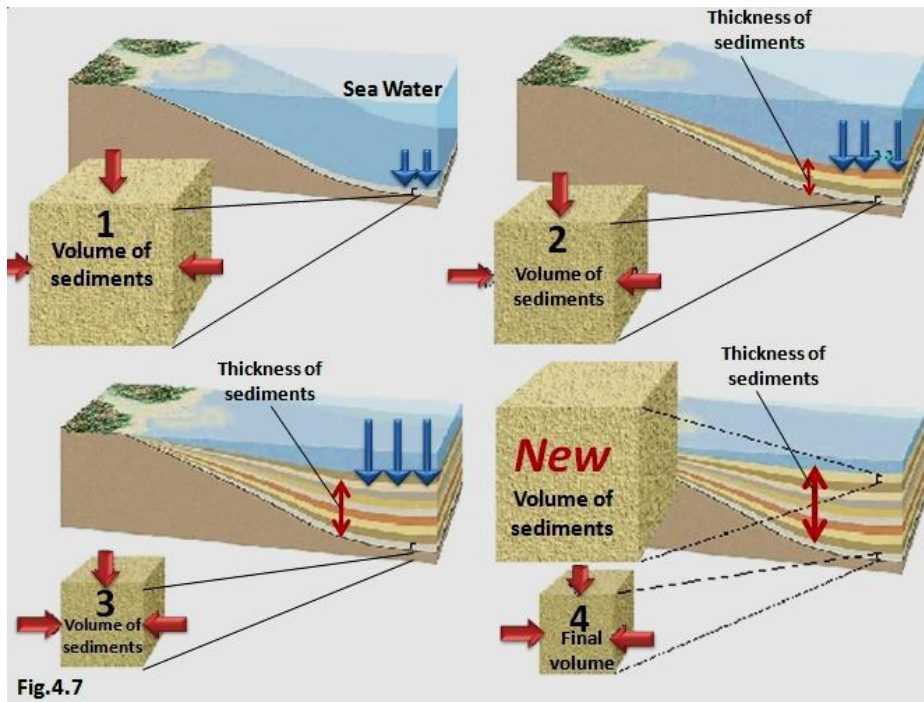
Eventually these particles and dissolved substance, called **sediments**, are deposited in the form of (Fig.4.6):

- a- Delta deposits. 1.
- b- Glacial moraine. 2.
- c- Dunes deposits. 3.
- d- Beach deposits. 4.

Next, the sediments undergo a process called **Lithification**, meaning "conversion to rock," either by:

- 1-Compaction. (Fig.4.7).
- 2-Cementation. (Fig.4.8). 1. 2. 3.

The result is **sedimentary rocks** such as **shale**, **sandstone**, and **conglomerate**. 4.

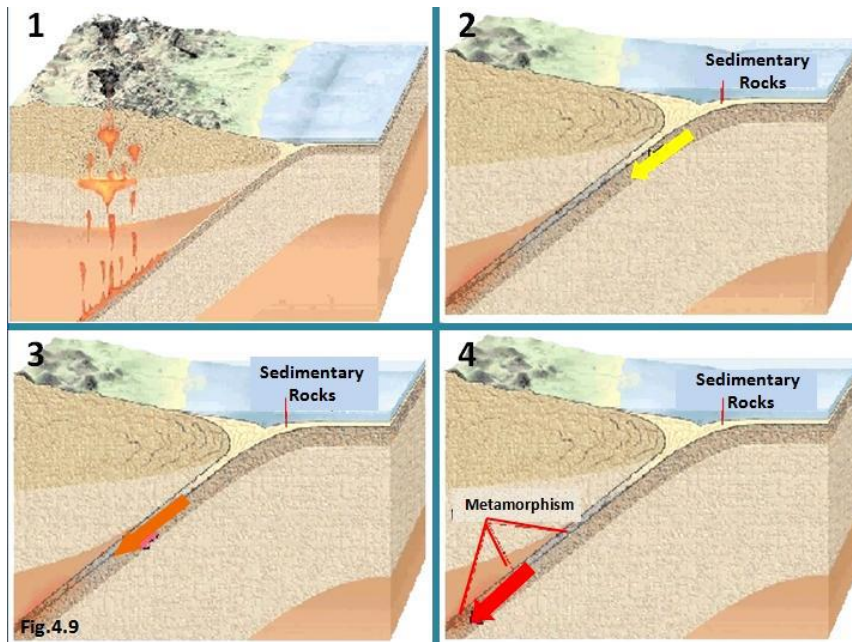


When sedimentary rocks are carried deep within earth, they will be subjected to great pressure and heat.

Any rocks subjected to strong compression forces and/or high temperatures change to metamorphic rocks.

When rocks in high temperature metamorphic environment are subjected to direct forces, they are easily folded.

Rocks that are transported to great depths may melt to **generate magma**. (Fig.4.9).



As we saw, rocks are transformed from one type to another in a **never-ending cycle**. Earth materials do not always follow the paths shown in the rock cycle diagram. It is just as likely that **other paths** will be followed. (Fig.4.10).

4.2- Introduction to igneous rocks:

Recall from the discussion of the **rock cycle** that **igneous rocks** form when molten rock cools and **crystallizes**.

Molten rocks (**magma**) originated in the **mantle** and **crust** as a result of partial melting of solid rock.

Because the magma body is less dense than the surrounding rocks, it works its way toward the surface, occasionally producing a volcanic eruption. (Fig.4.11). 1.

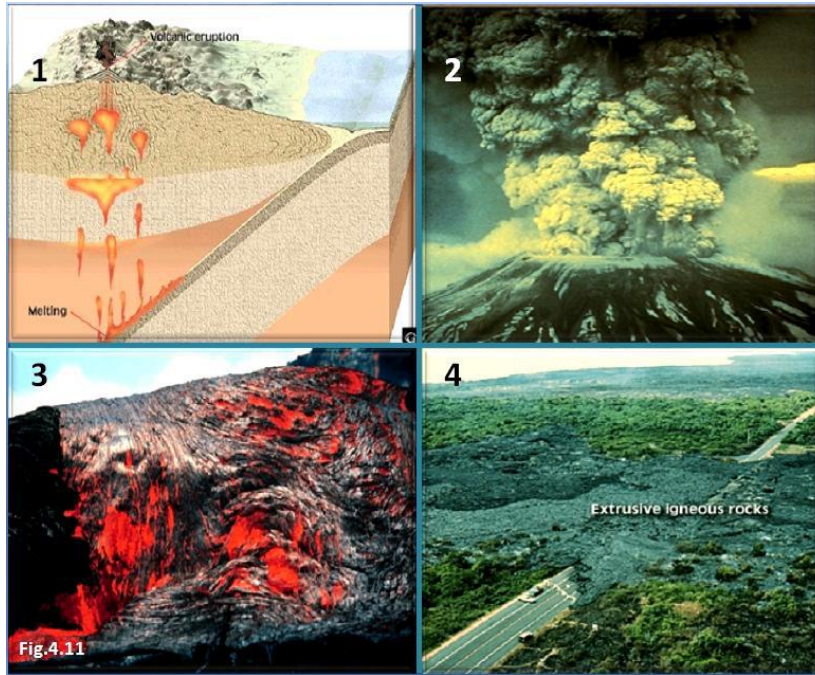
Volcanic eruptions may produce **pyroclastic debris** such as ash and cinders. 2.

Along with pyroclastic debris, volcanic eruption can produce extensive **lava flow**. 3.

Igneous rocks that form when lava solidifies are classified as **extrusive** or **volcanic igneous rocks**. 4.

Most magma never reaches the surface. Rather it crystallizes at depth to produce **intrusive** or **plutonic igneous rocks**. (Fig.4.12).

Although intrusive igneous rocks form at depth, uplifting and erosion often expose them at the surface. (Fig.4.13). 1 and 2.



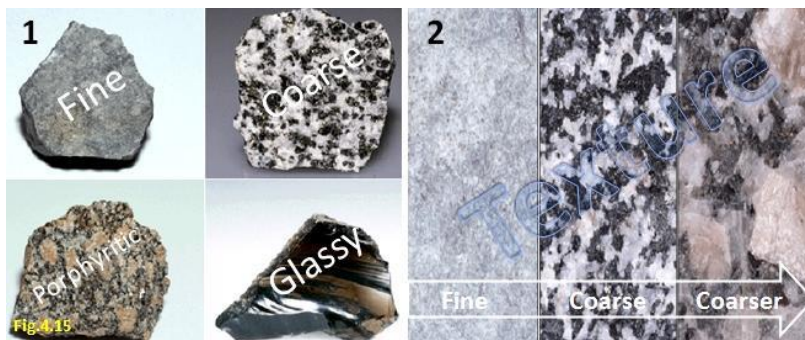
Intrusive igneous rocks are exposed in many places including Yosemite National Park (California). (Fig.4.14). 1. Stone mountain. 2.

To summarize, igneous rocks form when lava cools quickly at the surface. Or when magma crystallizes more slowly in a shallow **plutonic** like **sill**. 3. Or at great depth over very long spans of time. 4.

4.3- Texture of igneous rocks:

The rate of cooling greatly affects both the size and arrangement of the crystals, a property called **texture**. (Fig.4.15). 1.

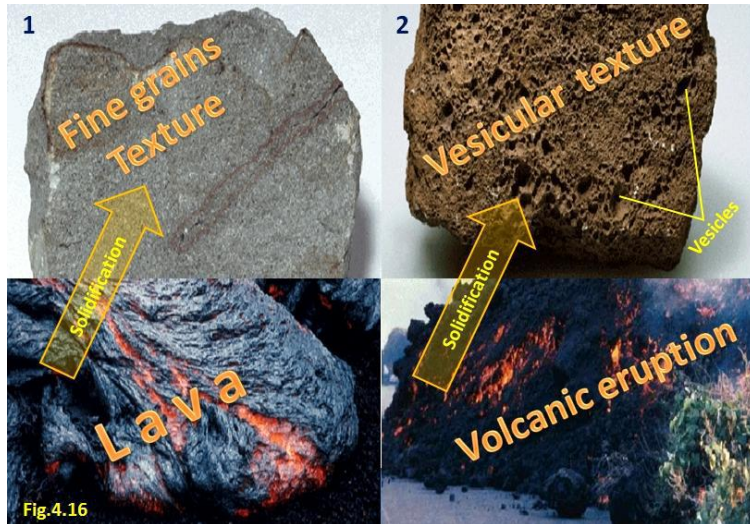
Rapid cooling produced **smaller crystals** and slower cooling allows time for **larger crystals** to form. 2.



Igneous rocks that form at the surface, or as small masses within the upper crust, possess a **fine-grained texture**.

Notice that the grains in fine-grained rocks are too small for individual minerals to be distinguished with the unaided eye. (Fig.4.16). 1.

Many fine-grained rocks contain voids leaved by gas bubbles that escaped as lava solidifies. These volcanic rocks usually form near the surface of lava flows and are said to a **vesicular texture**. 2.



When large masses of magma solidify at depth, they form igneous rocks that exhibit a coarse-grained texture.

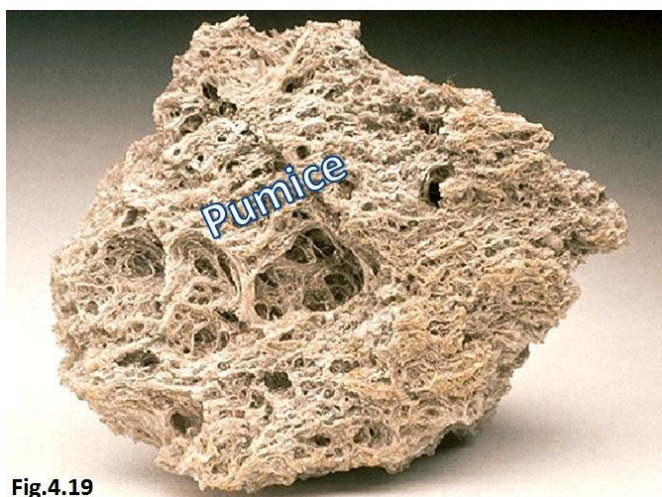
In contrast to fine-grained rocks, the individual minerals in coarse-grained rocks can be identified with the unaided eye. (Fig.4.17).

Rapid cooling of **lava** may generate a **glassy texture**. Glass results when the ions are unordered, that is, they have not formed an orderly crystalline structure.

Rocks with a glassy texture, like **obsidian**, also form when silica-rich lava is extruded as a viscous mass that solidifies as a glass. (Fig.4.18).

During some volcanic eruptions, silica-rich lava is ejected into the atmosphere where it is cooling quickly.

These events can generate a foamy mass of fine shards of intertwined glass called **pumice**. (Fig.4.19).



Some igneous rocks have large crystals embedded in a matrix of smaller crystals.

These rocks are said to have a **porphyritic texture**.

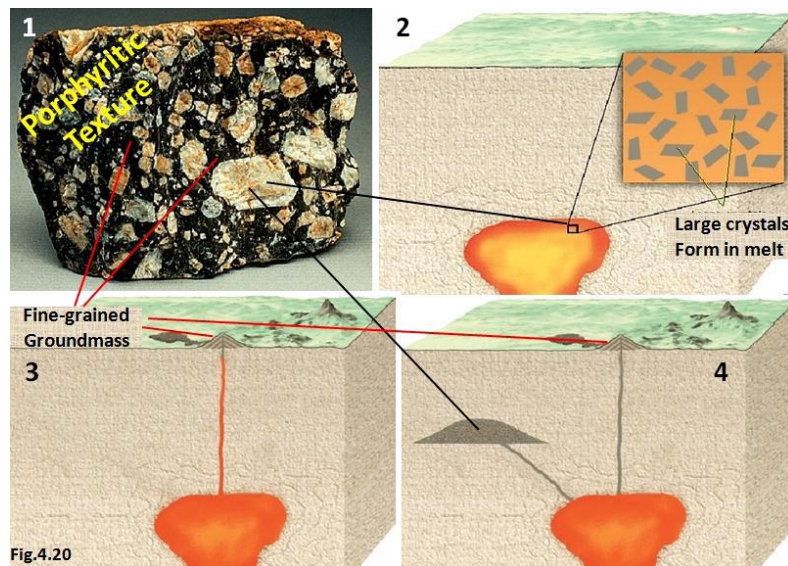
The large crystals in such a rock are referred to as **phenocrysts**, with the matrix of smaller crystals called (**fine-grained**) **groundmass**. (Fig.4.20). 1.

Porphyritic rocks form when certain minerals begin to crystallize and grow quite large before others begin to form. 2.

Then the magma containing these large crystals migrates to a new environment where cooling takes place more rapidly. 3.

In this situation, the rock will have a **porphyritic** texture as shown in the sample below.

In other situation, the magma may migrate to a smaller intrusive body where cooling occurs more rapidly, but still slowly enough to produced visible crystals. 4.



4.4- Compositions of igneous rocks:

Igneous rocks come in a **wide variety** of mineral composition. Igneous rocks are mainly composed of **silicate minerals**.

These silicate minerals are divided into two major groups based on their mineral makeup:

- **The dark silicate.**
- **The light silicate.**

The dark silicates are rich in iron and / or magnesium. **It is their iron content that gives the dark silicates their color.**

Igneous rocks can be composed mainly of **dark silicate minerals**. (Fig.4.21).

Dark Silicate	Light Silicate
Olivine (Mg,Fe)SiO ₄	(Muscovite) K ₂ Al ₄ [Si ₃ AlO ₁₀] ₂ (OH,F) ₄
Pyroxene group (Augite) Ca(Mg,Fe)Si ₂ O ₆	Orthoclase (KAlSi ₃ O ₈) Feldspar
Amphibole group (Hornblende) (CaMgFeAl(OH) ₂ (SiAl) ₄ O ₁₁)	Plagioclase (NaCa)Al ₂ Si ₂ O ₈ Feldspar
Dark mica (biotite) K ₂ (Mg,Fe) ₆ [Si ₃ AlO ₁₀] ₂ (OH,F) ₄	Quartz SiO ₂

By the contrast, the **light silicates** contain greater amounts of potassium, sodium and calcium rather than iron and magnesium.

Igneous rocks can be composed mainly of **light silicate minerals**.

(Fig.4.22).

Or, as is often the case, igneous rocks are composed of minerals from **both groups** in various combinations and.

(Fig.4.23).

Near one end of the continuum are rocks composed mainly of the light-colored silicate.

These granitic rocks contain 70% percentage silica and are abundant in the continent crust. (Fig.4.24).

Basaltic rocks are rich in dark minerals and contain about 50 percentage silica.

Basalt makes up the ocean floor as well as lava flows and volcanic structures.

(Fig.4.25).

In addition to these major groups, igneous rocks with a wide variety of mineral composition also exist.

Why does such a large variety of igneous rocks exist?

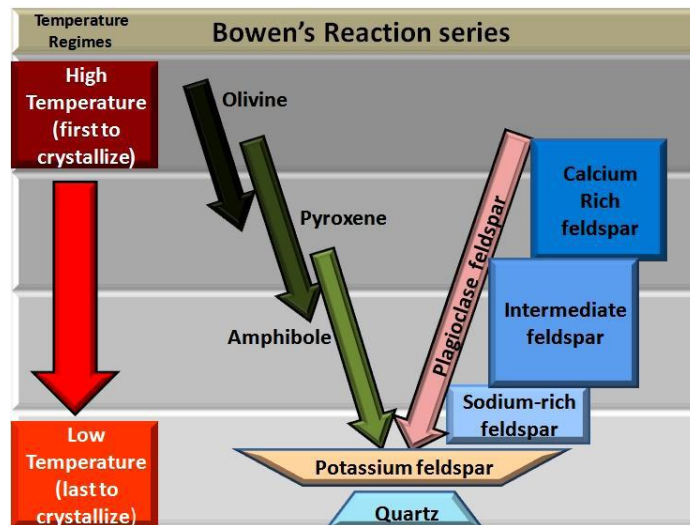
The answer:

when the composition of magma appears to be relatively homogeneous around the globe.

N. L. Bowen was the first to demonstrate how a single magma body could generate a variety of igneous rocks.

Bowen demonstrates that minerals with a higher melting point, such as olivine, crystallize first, while minerals with a low melting point, such as potassium feldspar and quartz, crystallize much later.

As you might expect, minerals that form in the same temperature zone are found together in the same igneous rocks as shown below:



Igneous rocks that are composed of the earliest formed minerals, i.e., olivine and pyroxene, are said to have an **(ultramafic)** composition. Igneous rocks composed mainly of pyroxene and calcium-rich plagioclase feldspar has a basaltic composition (**mafic**).

While rocks composed of amphibole and plagioclase feldspar are said to have an **intermediate** or **andesitic composition**. Igneous rocks formed from the last minerals to crystallize, namely quartz, potassium feldspar and sodium-rich plagioclase feldspar, are said to have a **granitic composition (felsic)**.

4.5- Naming igneous rocks:

Igneous rocks are named based on:

1- Texture.

2- Mineral composition.

Using the various igneous textures and mineral composition categories, we can develop the table that is used to name the basic igneous rocks.

For example, a fine-grained rock with a granitic composition is called **rhyolite**.

And coarse-grained rocks composed of quartz and potassium feldspar are called **granite**.

A porphyritic rock with a fine-grained groundmass (matrix) and andesitic composition is called **andesite porphyry** ... f h as shown below:

Chemical Composition		Granitic (felsic)	Andesitic (intermediate)	Basaltic (mafic)	Ultramafic
Dominant Minerals		Quartz Potassium feldspar	Amphibols Intermediate Plagioclase feldspar	Pyroxine Calcium-rich Plagioclase feldspar	Olivine Pyroxine
Color		Light	Medium	Dark	Dark
TEXTURE	Coarse grained	<i>Granite</i>	<i>Diorite</i>	<i>Gabbro</i>	<i>Peridotite</i>
	Fine grained	<i>Rhyolite</i>	<i>Andesite</i>	<i>Basalt</i>	<i>Komatite (rare)</i>
	Porphyritic	"Porphyry" follows any of the above names Whenever there are appreciable phenocrysts			
	Glassy	<i>Obsidian</i> (compact glass) <i>Pumice</i> (frothy glass)			

- 1- Igneous rocks originate when hot, molten material called -----, a- sediments. b- volcano. c- earthquake. d- magma. 2- Igneous rocks rich in dark silicate minerals with about 50 percent silica are said to have a ----- composition. a- fine-grained. b- basaltic. c- rhyolitic. d- granitic. 3- Which one of the following is NOT a possible product of a volcanic eruption? a- ash. b- pyroclastic debris. c- cinder. d- marble. 4- An igneous rock with less than 15 percent dark minerals would have a ----- composition. a- basaltic (mafic). b- detriatal (lithic). c- andesitic (intermediate). d- granitic (felsic). 5- When the minerals in igneous rocks cannot be identified; the composition can be estimated based on the percentage of phenocrysts present in the rock. a- true. b- false. 6- Which one of the following greatly affects both the size and arrangement of mineral crystals in igneous rocks? a- Composition of the rock surrounding the magma. b- specific gravity of the magma or lava. c- rate of tectonic uplift. d- rate of cooling of the magma or lava.
- 7- Basalt makes up the ocean crust as well as lava flows and volcanic structure on land. a- true. b- false. 8- In a rock with porphyritic texture, the large crystals are referred to as -----, a- groundmass. b- erratic. c- phenocrysts. d- orthoclase. 9- Rocks that contain voids leave by gases that escaped as lava solidifies are said to exhibit a ----- texture. a- coarse-grained. b- vesicular. c- fine-grained. d- porphyritic. 10- Igneous rocks that form when lava solidifies are classified as extrusive or volcanic igneous rocks. a- true b- false 11- Which of these rocks is composed almost entirely of ferromagnesian minerals? a- granite b- basalt c- rhyolite d- peridotite 12- Igneous rocks that form from the last minerals to crystallize from magma will have a ----- composition consisting of quartz, potassium feldspar and sodium-rich plagioclase feldspar. a- andesitic (intermediate) b- basaltic (mafic) c- mafic (felsic) d- granitic (felsic)

2- Sedimentary Rocks:

4.2- Introduction to sedimentary rocks:

Recall from the **rock cycle** that **sedimentary rocks** form when the products of weathering are transported to a new location where they are deposited and eventually **lithified** into solid rock.

Weathering which begins the process can be either:

A- Mechanical weathering. 1.

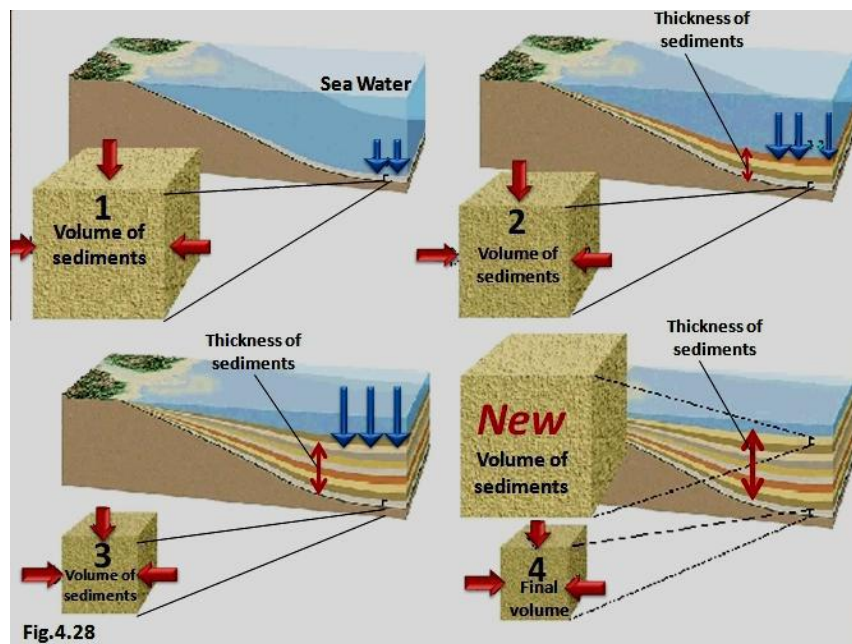
B- Chemical weathering. 2.

(Fig.4.26).

Erosion agents such as running water, wind, waves and ice remove the products of weathering and transport them to other locations.

Eventually, these solids particles and dissolved substance, called **sediments**, are deposited. (Fig.4.27)

Next, the sediments undergo **Lithification**, meaning "conversion to rock" by **compaction**. (Fig.4.28).



And/or by **cementation** as percolating water coats the sediments with mineral matters, and gradually cements the particles together. The result is sedimentary rocks such as **shale**, **sandstone** and **conglomerate**.

(Fig.4.29)

Some sedimentary rocks are not compacted or cemented but form as solid masses of intergrowth crystals.

Rock salt is one example.

(Fig.4.30).

4.3- Types of sedimentary rocks:

a-Detrital sedimentary rocks.

b-Chemical sedimentary rocks.

c-Organic (biochemical) sedimentary rocks.

a- Detrital sedimentary rocks.

The products of weathering include materials that originated and are transported as solid particles. (Fig.4.31). 1.

These particles are called **detritus** and the sedimentary rocks they form are called **detrital sedimentary rocks**. 2.

Two minerals are especially common in Detritus rocks:

1- Clay.

2- Quartz.

The table below is showing the products of weathering:

Products of Weathering		
Original minerals	Weathers To produce	Released Into solution
Quartz	Quartz grains	Silica
Feldspar	Clay minerals	Silica K, Na, Ca
Amphibole (hornblende)	Clay minerals Limonite, Hematite	Silica Ca, Mg
Olivine	Limonite Hematite	Silica Mg

Geologists use particle size to distinguish among detrital sedimentary rocks.

The common sediment name for all particles **larger than 2 millimeters** is **gravel**.

When gravel-sized particles predominate, the rock is called **conglomerate** if the particles are **rounded** and **breccias** if the pieces are **angular**.

The particles in **conglomerate** become **rounded** as they are transported, most frequently by streams. (Fig.4.32). 1.

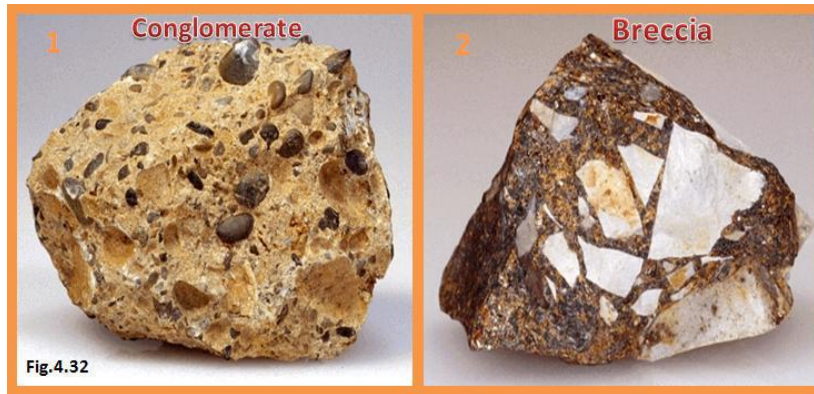
The **angular** pieces of brachia indicate the particles were not transported very far from their source prior to deposition. 2.

The common sediments name for particles between 1/16 mm and 2mm is **sand** and **sandstone**, And it is the name given to rocks when sand-sized grains dominate.

Because it is very durable, **quartz** is the predominant mineral in the most **sandstone**. (Fig.4.33). 1.

When substantial quantities of feldspar are present in sandstone, the rock is called **arkoses**. 2.

The presence of abundant feldspar suggests there was little chemical weathering of the sediments, something we might associate with a **dry climate**.



When the tiniest silt and clay- sized particles predominate, the common sediment name is **mud** and **shale** or **mudstone** is the name given the rock.

The table below is showing the particles size classification for Detritus rocks:

Particle Size Classification for Detrital Rocks			
Size range (millimeter)	Particle name	Common Sediment name	Detrital name
>256	Boulder	Gravel	Conglomerate or Breccia
64 – 256	Cobble		
4 – 64	Pebble		
2 - 4	Granule		
1/16 - 2	Sand	Sand	Sandstone
1/256 – 1/16	Silt	Mud	Shale or Mudstone
<1/256	Clay		

In a nontechnical context, the term "**Shale**" is used for all fine-grained sedimentary rocks. (Fig.4.34). 1.

Because shale crumbles easily, it forms gentler slopes of weathered debris.

By comparison, outcrops of more durable rocks like sandstone produced, steep cliffs.

b- Chemical sedimentary rocks:

Unlike detritus rocks which form from the solid products of weathering, the source of sediments for **chemical sedimentary rocks** is **materials dissolved in water**. (Fig.4.35). 1.

Three kinds of chemical sedimentary rocks:

1- When materials in solution precipitate, it forms chemical sediments, which become rocks such as limestone, chart and rock salt.2.

2- Precipitation of dissolved materials occurs by inorganic processes such as evaporation, temperature change and chemical activity.3.

3- Or by life-processes of water-dwelling organism. These materials are called **biochemical sediments**. 4.

Did you know shells are an example of (biochemical) sediments?

Limestone: the most abundant chemical sedimentary rock, is composed chiefly of the mineral **calcite**. (Fig.4.36). 1. Most limestone has a biochemical origin.

Example includes **coquina**, Which consists of shell fragments. 2.
Chalk: which is made of the hard parts of microscopic marine organisms. 3.
 And limestone that originated as **coral reefs**. 4.

Travertine: is Limestone with an inorganic origin, which is often seen decorating caves. (Fig.4.37). 1.

Halite: Evaporates form when evaporation causes minerals to precipitate from water. Such minerals include halite (NaCl), the main component of rock salt. 2.

Chart: is the name used for a number of hard, compact rocks made of microcrystalline silica.

These rocks may have either inorganic or a biochemical origin. It usually is not possible to determine this by looking at a hand sample.3. 4. 5.



Gypsum: ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), the main ingredient of rock gypsum. (Fig.4.38). 1.

Thick **evaporate deposits** may form when a large body of seawater isolated by reefs or sand barriers. 2

4.4- Sedimentary environments:

Sedimentary rocks form as layer upon layer of sediments accumulates. These **strata** are the single **most characteristic** of sedimentary rocks.

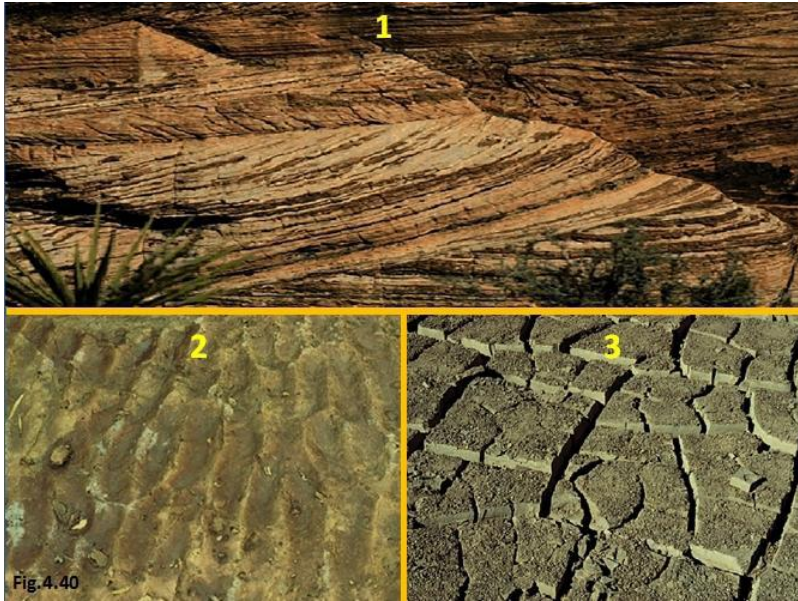
Each layer is unique. The variations among strata reflect the conditions under which each layer was deposited. (Fig.4.39).

Sedimentary rocks show a variety of structures that help us to interpret **past geologic conditions** like:

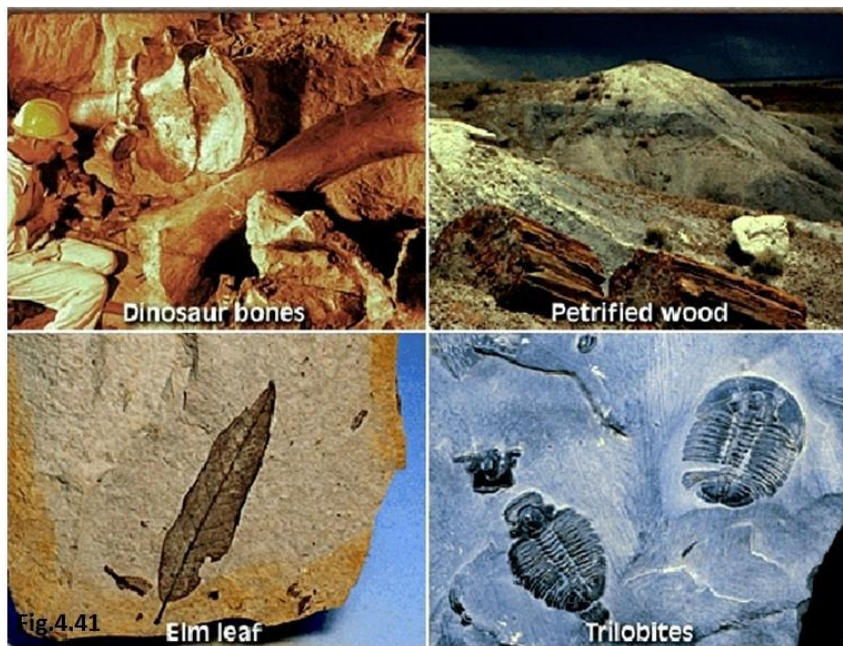
Cross-bedding: occurs in sand dunes and certain stream deposits. (Fig.4.40). 1.

Ripple – marks: are associated with currents of air and water or with the back and forth movement of waves. 2.

Mud-cracks: When they are preserved, they indicate alternating wet and dry conditions and are associated with such places as desert basins and shallow lakes. 3..



Fossils: They are preserved in sedimentary rocks, and important keys to **past environments**. (Fig.4.41).



The size of particles in sedimentary rocks provides useful information about **environments of depositions**. (Fig.4.42). 1 and 2.

Currents of water and air sort particles by size. **The stronger the current, the larger the particles size carried.** 3 and 4.

For example, in very **turbulent water** only large gravel-sized particles can settle out. 5.

Whereas fine particles settle in the waters of a **swamp, lake** or **lagoon**. 6.

The mineral composition of the rock can also contribute useful information about past environment.

For example, Evaporates can indicate an **arid** setting. (Fig.4.43). 1.
And certain limestone, like **coquina**, can indicate a warm, shallow marine environment. 2.

- 1- Which rock type is most likely associated with a high-energy environment such as a turbulent stream? a- conglomerate. b- shale. c- rock salt. d- chart.
- 2- Rock salt and rock gypsum are example of ----- sedimentary rocks. a- detritus. b- biochemical. c- evaporate.
- 3- The percentage of abundant feldspar in a sedimentary rock suggested that advanced stages of chemical weathering have taken place. a- true. b- false.
- 4- When substantial quantities of feldspar are present in sandstone, the rock is called: a- agate. b- rock gypsum. c- arkoses. d- greywacke.
- 5- The sizes of particles in detritus sedimentary rocks often indicate the energy of transporting medium. a- true. b- false.
- 6- The most abundant chemical sedimentary rock is ----- . a- shale. b- conglomerate. c- chart. d- none of the above.
- 7- Angular pieces in detrital sedimentary rocks indicate the particles were not transported very far from their source prior to deposition. a- true. b- false.
- 7- Compaction and cementation are examples of this process. a- lithification. b- crystallization. c- weathering. d- fusion. e- metamorphism.
- 8- Evaporates are examples of biochemical sedimentary rocks. a- true. b- false.
- 10- Compaction is a very important Lithification process for which sediments? a- mud. b- sand. c- gravel.
- 10- Which common mineral found in igneous rocks is most abundant in detritus sedimentary rocks? a- amphibole. b- biotitic. c- Plagioclase. d- quartz.
- 11- This detritus sedimentary rock consist primary of rounded gravel-size particles. a- breccias. b- coquina. c- shale. d- conglomerate.
- 13- Sedimentary rocks form when the products of ----- are transported to a new location where they are deposited and eventually ----- into solid rock. a- melting; crystallized. b- deposition; eroded. c- crystallization; metamorphosed. d- tectonics, weathered. e- weathering, lithified.

- 15- Which sedimentary rock consists of materials that originated and were as solid particles? a- sandstone. b- rock salt. c- chert. d- travertine limestone.
- 16- Detritus sedimentary rocks are made primary of the products of mechanical weathering. a- true. b- false.
- 17- Geologists use ----- to distinguish among detrital sedimentary rocks. a- Particle size. b- method of formation. c- color. d- the location of source material. e- none of the above.
- 18- Precipitation of dissolved material by the life processes of water-dwelling organisms produces material called ----- sediments a- biochemical. b- secondary. c- detritus. d- classic.
- 19- The common name for sediment consisting of particles between 1/16 mm and 2 mm is -----, a- clay. b- silt. c- cobble. d- sand.
- 20- Agate, jasper and flint are all forms of chert. a- true. b- false.
- 20- Which one of the following is NOT a sedimentary structure or feature that helps geologists interpret past geological conditions? a- vesicles. b- mud cracks. c- Particle sorting. d- ripple marks. e- cross-bedding.

3- Metamorphic Rocks:

4.3- Introduction to Metamorphic Rocks:

Recall from the discussion of the rock cycle that metamorphism involves the transformation of pre-existing rocks.

Metamorphic rocks can form from:

- 1- **Igneous rocks.** (Fig.4.44). 1.
- 2- **Sedimentary rocks.** 2.
- 3- **Other metamorphic rocks.** 3.



4.4- Agents of Metamorphism:

The agents of metamorphism are:

- 1- **Heat.**
- 2- **Pressure (Stress).**
- 3- **Chemically active fluids.**

These agents commonly acting together as shown below:

1- Heat:

Perhaps the most important agent of metamorphism is **heat**, because it provides the energy to drive chemical reactions. (Fig.4.45).

Rocks found near the surface of earth may be subjected to intense heat when they are faced by **magma**, a process called **contact metamorphism**.

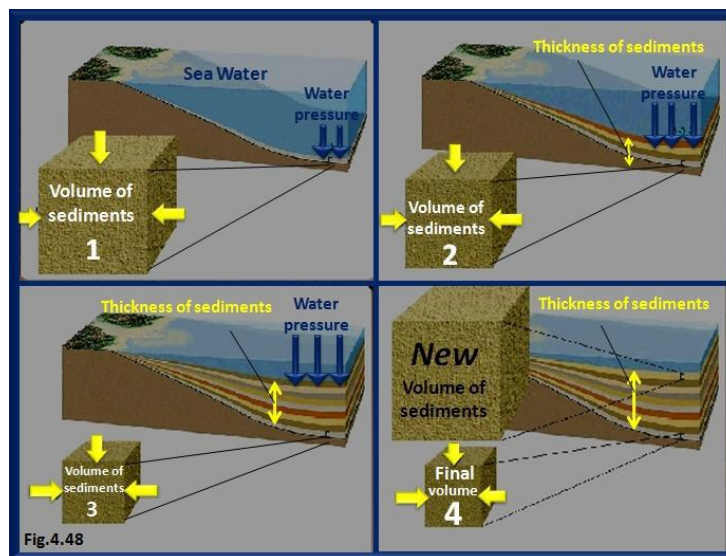
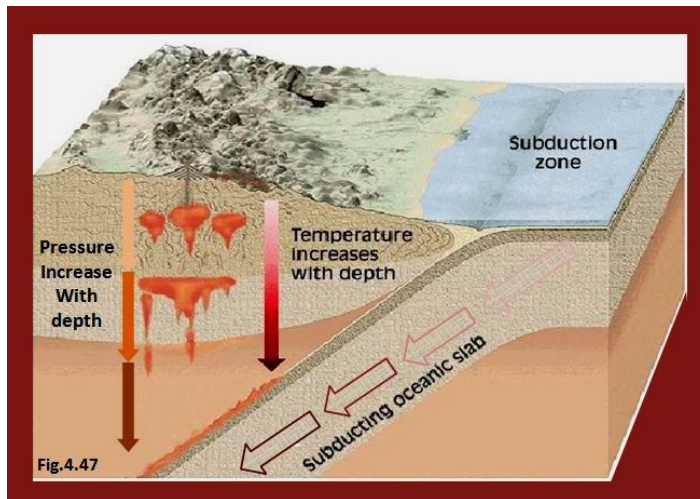
Here the adjacent host rock is "**baked**" by the emplaced magma. (Fig.4.46).

Rocks may also be subjected to high temperature if they are carried deep within earth.

2- Pressure:

Pressure, like temperature, also increases with depth. (Fig.4.47).

Buried rocks are subjected to pressure, or stress exerted by the loads above it. (Fig.4.48).



The **confining pressure** is applied equally in all directions and causes a reduction in volume, thereby generating a more compact (dense) rock. (Fig.4.49).

Rocks are also subjected to forces during mountain building that are **unequal** and in different directions, called **differential stress**. (Fig.4.50).

3- Chemically active fluids:

most commonly hot water containing ions in solution, also enhance the metamorphic process.

For example, along oceanic ridge, sea water circulates through hot basaltic rocks, transforming the existing iron-rich minerals into metamorphic minerals such as **serpentine** and **talc**. (Fig.4.51).

4.5- Textural and Mineralogical Changes:

The degree of metamorphism is reflected in the rock's texture and/or mineral composition.

When rocks are subjected to **low-grade metamorphism**, they become more compact and thus denser. (Fig.4.52).

During metamorphism, the crystals of some minerals, such as micas which have a sheet structure, and hornblende which has an elongated structure, will recrystallize with a preferred orientation.

The new orientation will be essentially **perpendicular to the direction of stress**. (Fig.4.54).



The resulting mineral alignment usually gives the rock **layered or banded** appearance termed **foliation**. (Fig.4.55).

Not all metamorphic rocks have a foliated texture. Metamorphic rocks composed of **only one mineral** that forms equidimensional crystals are generally **nonaffiliated**. (Fig.4.56).

In some environments, new minerals are formed during the metamorphic process. For example, rocks adjacent to a large magma body would be altered by ion-rich hydrothermal solutions released during the later stages of crystallization. (Fig.4.57).

- 1- When a rock is buried it is subjected to greater confining pressure which tends to make the rock more -----, a- active. b- elongated. c- fragile. d- dense.
- 2- Which one of the following metamorphic rocks is generally nonaffiliated? a- marble. b- mica schist. c- slate. d- gneiss.
- 3- Nonaffiliated metamorphic rocks are usually composed of -----, a- elongated mineral grains. b- equidimensional mineral grains. c- a mixture of both above.
- 4- What is the major source of heat for contact metamorphism? a- deep burial. b- frictional heat created by moving faults. c- heat from the decomposition of minerals. d- heat from a nearby magma body.
- 5- Rocks subjected to intense heat when they are intruded by magma undergo process called -----, a- tectonic metamorphism. b- searing. c- contact metamorphism. d- thermal modification.
- 6- The "layered" or banded" appearance resulting from mineral alignment in a metamorphic rock is termed: a- Pseudo-crystallization. b- bedding. c- foliation. d- orientation.
- 7- Metamorphic rocks can form from other metamorphic rocks. a- true. b- false.
- 8- Which one of the following is NOT an agent of metamorphism? a- Pressure (stress). b- heat. c- crystallization. d- chemically active fluids.
- 9- Which one of the following is a foliated metamorphic rock? a- quartzite. b- anthracite coal. c- granite. d- gneiss.
- 10- The most common chemically active fluids involved in the metamorphic process are hot water containing ions in solution. a- true. b- false.