1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Rocks and Minerals – Part 1
Module Id	kegy_10501
Pre-requisites	Basic knowledge about metals, non- metals, magma or lava.
Objectives	After going through this Module, the learners will be able to : • Acquire knowledge and understanding of different minerals. • They will understand the characteristics of Mineral. • They will be able to differentiate between metallic and non-metallic minerals. • They will learn about the formation of different types of rocks. • They will come to know about rock cycle.
Keywords	Minerals, metallic minerals, non-metallic minerals, rocks, petrology, magma, lava igneous rocks, sedimentary rocks, metamorphic rocks.

2. Development Team

Role	Name	Affiliation
National MOOC Coordinator (NMC)	Prof. Amarendra P. Behera	CIET, NCERT, New Delhi
Program Coordinator	Dr. Mohd. Mamur Ali	CIET, NCERT, New Delhi
Course Coordinator (CC) / PI	Prof. Aparna Pandey	DESS, NCERT, New Delhi
Course Co-Coordinator / Co-PI	Dr. Archana	CIET, NCERT, New Delhi
Subject Matter Expert (SME)	Rajeev Kumar Sinha	NCERT textbook " Fundamentals of Physical Geography" TGT (Geography) St. Xavier's Sr. Sec. School, Delhi
Review Team	Prof. S.R. Jog Dr. Preeti Tiwari	Department of Geography, University of Pune, Pune Shivaji College, New Delhi

Table of Contents:

The earth is composed of various kinds of elements. These elements are in solid form in the outer layer of the earth and in hot and molten form in the interior. About 98 per cent of the total crust of the earth is composed mainly of eight elements like oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium and the rest of the earth is constituted by titanium, hydrogen, phosphorous, manganese, sulphur, carbon, nickel and other elements.

Sl. No.	Elements	Weight (%)
1.	Oxygen	46.60
2.	Silicon	27.72
3.	Aluminium	8.13
4.	Iron	5.00
5.	Calcium	3.63
6.	Sodium	2.83
7.	Potassium	2.59
8.	Magnesium	2.09
9.	Others	1.41

Table: The Major Elements of the Earth's Crust

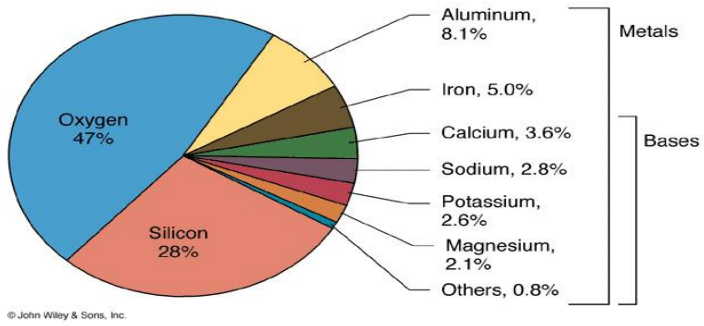


Fig No.1 Earth's Crust Composition

Source: http://geologycafe.com/images/crust_composition.jpg

The elements in the earth's crust are rarely found exclusively but are usually combined with other elements to make various substances. These substances are recognised as minerals. Thus, a **mineral** is a naturally occurring organic and inorganic substance, having an orderly atomic structure and a definite chemical composition and physical properties. A mineral is composed of two or more elements. But, sometimes single element minerals like sulphur, copper, silver, gold, graphite etc. are found.

Though the number of elements making up the lithosphere arelimited, they are combined in many different ways to make up many varieties of minerals. There are at least 2,000 minerals that have been named and identified in the earth crust; but almost all the commonly occurring ones are related to six major mineral groups that are known as major rock forming minerals. Minerals are all around us. Minerals are used in making everything from a tiny pin to an aeroplane. But have you ever wondered where these minerals come from? There are so many types of minerals and all these are formed in different ways. Inside the earth there are places where rocks melt and these molten rocks inside the earth form magma. The basic source of all minerals is the hot magma in the interior of the earth. Magma can be hotter than 1000 degree Celsius.

Magma is a molten mixture of substances, which moves up through the earth's crust but does not always reach the surface. Either it may solidify below the earth surface or it solidifies when it reaches on to the surface. When magma reaches on the earth surface, it is termed as lava**.** Rocks form quickly on the earth surface so the mineral crystals that are very small in size as compared to the mineral crystals that are formed inside the earth surface. One such example is rhyolite, which contains similar minerals to granite.

Fig No. 2 Magma

Source:https://upload.wikimedia.org/wikipedia/commons/8/82/Pahoehoe_toe.jpg

The process of cooling of magma is very slow, as it rises towards the earth surface, it may take thousands of years to solidify inside the earth. As magma cools, crystals began to appear and a systematic series of minerals are formed in sequence to solidify into rocks. Minerals such as coal, petroleum and natural gas are organic substances found in solid, liquid and gaseous forms respectively.

Minerals are not evenly distributed over space. They are concentrated in a particular area or rock formations. Some minerals are found in areas which are not easily accessible. Minerals are formed in different types of geological environments and under varying conditions. They are created by natural processes without any human interference.

Fig. No- 3 Dioptase

https://upload.wikimedia.org/wikipedia/commons/c/c8/Dioptase-36918.jpg

The nature and physical characteristics of some important minerals are discussed below:

Physical Characteristics of Minerals

(i) *External crystal form* is determined by the internal arrangement of molecules as cubes, octahedrons, hexagonal prisms, etc.

(ii) *Cleavage* is the tendency to break in given directions producing relatively plane surfaces. This result from the internal arrangement of the molecules .They may cleave in one or more

directions and at any angle to each other.

Fig No .4 Mica Sheet

Source : https://upload.wikimedia.org/wikipedia/commons/5/50/MicaSheetUSGOV.jpg

(iii) *Fracture* when the internal molecular arrangement is so complex that there are no planes of molecule; the crystals will break in an irregular manner, not along planes of cleavage.

(iv) *Lustre*s the appearance of a material without regard to colour. Each mineral has a distinctive lustre like metallic, silky, glossy etc.

Fig No .5 Pyrite

Source: https://en.wikipedia.org/wiki/Lustre_(mineralogy)#/media/File:Pyrite_3.jpg

(v) *Colour* — Some minerals malachite, azurite, chalcopyrite etc. Have a characteristic colour determined by their molecular structure and other minerals may be coloured by impurities. For example, because of impurities quartz may be white, green, red, yellow etc.

Fig. No.6 Quartz

Source: https://upload.wikimedia.org/wikipedia/commons/c/ce/Quartz_Br%C3%A9sil.jpg

(vi) *Streak* is the colour of the ground powder of any mineral. It may be of the same colour as the mineral or it may differ for example malachite is green and gives a green streak, fluorite is purple or green but gives a white streak.

(vii) *Transparency* allows light rays pass through so that minerals objects can be seen plainly; translucency allows light rays to pass through some minerals so that objects cannot be seen; clearly. Opaque minerals will not allow light to pass at all.

(Viii) *Structure* refers to the particular arrangement of individual crystals structure may be fine, medium coarse grained or fibrous — separable, divergent, radiating.

(ix) *Hardness* is the relative resistance to being scratched. Ten minerals are selected to measure the degree of hardness on a scale from 1-10. They are: 1. talc; 2. gypsum; 3. calcite; 4. fluorite; 5. apatite; 6. feldspar; 7. quartz; 8. topaz; 9. corundum; 10. Diamond. On this scale, a fingernail is 2.5 and glass or knife blade is 5.5.

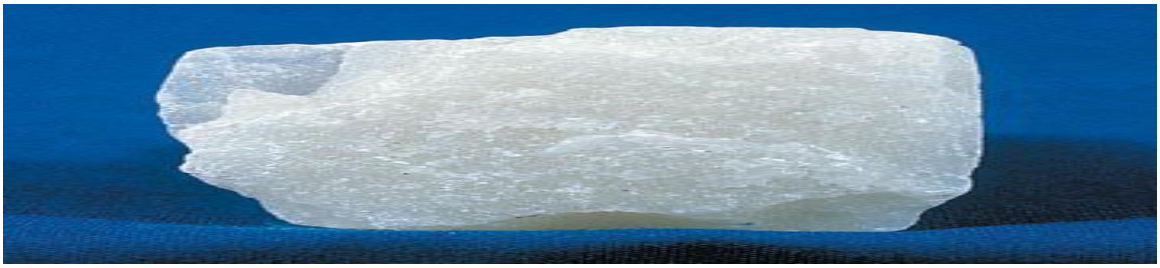


Fig No.7 Talc Block

Source :https://upload.wikimedia.org/wikipedia/commons/f/fd/Talc_block.jpg

(x) *Specific gravity* is the ratio between the weight of a given object and the weight of an equal volume of water. An object is weighed in air and then weighed in water. The weight in air is divided by the difference of the two weights.

Some Mmjor minerals and their characteristics

Feldspar: Silicon and oxygen are common elements in all types of feldspar, and sodium potassium, calcium, aluminium etc. are found in specific feldspar varieties. Half of the earth's crust is composed of feldspar. It has light cream to salmon pink colour. It is used in ceramics and glass making.

Fig No 8 Feldspar

Source : https://upload.wikimedia.org/wikipedia/commons/a/a1/2010_-_Feldspar.jpg

Quartz: It is one of the most important components of sand and granite. It consists of silica. It is a hard mineral virtually insoluble in water. It is white or colourless and used in radio and radar. It is one of the most important components of granite.

Pyroxene: Pyroxene consists of calcium, aluminium, magnesium, iron and silica. Pyroxene forms 10 per cent of the earth's crust. It is commonly found in meteorites. It is green or black in colour.

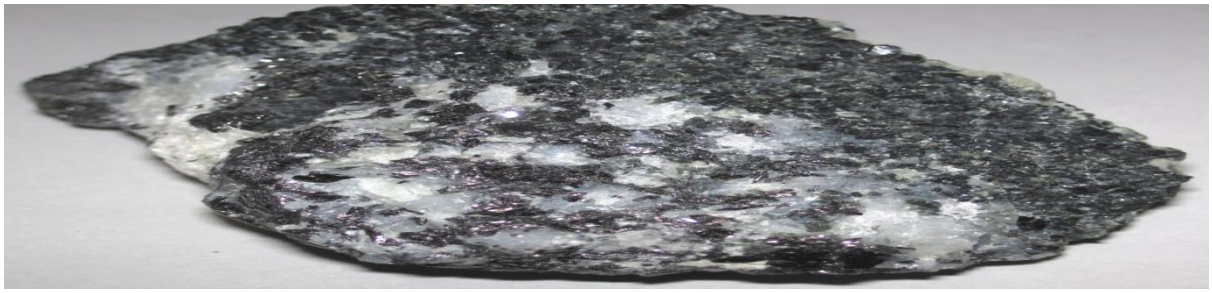


Fig No, 9 Graphite-Pyroxene

Source :https://c1.staticflickr.com/2/1538/25959925080_cb2f223666_b.jpg

4. **Amphibole:** Aluminium, calcium, silica, iron, magnesium are the major elements of amphiboles. They form 7 per cent of the earth's crust. It is in green or black in colour and is used in the asbestos industry. Hornblende is another form of amphibole.

Fig .No, 10 Hornblende

Source::https://c1.staticflickr.com/1/424/32545259415_a2d2280715_b.jpg

Mica: It comprises potassium, aluminium, magnesium, iron, silica etc. It forms 4 per cent of the earth's crust. It is commonly found in igneous and metamorphic rocks. It is used in electrical instruments.

Olivine: Magnesium, iron and silica are major elements of olivine. It is used in jewellery. It is usually a greenish crystal, often found in basaltic rocks. Besides these main minerals, other

minerals like chlorite, calcite, magnetite, haematite, bauxite and barite are also present in some quantities in the rocks.

Fig No 11. Magnesium Crystals

Source: https://upload.wikimedia.org/wikipedia/commons/3/3f/Magnesium_crystals.jpg

Classification of Minerals:

Generally, minerals are classified into two groups: metallic minerals and non-metallic minerals

Metallic Minerals

Metallic minerals are of great importance as they are used for a variety of purposes. They contain metals and are hard, malleable and ductile. They are good conductors of heat and electricity. Metallic minerals can be sub-divided into three types:

(i) **Precious metals:** These are rare but often colourful, naturally occurring metallic element of very high economic value. Examples are gold, silver, platinum etc. Any mineral is called precious if it is rare. Most precious metals are less reactive than other metals.

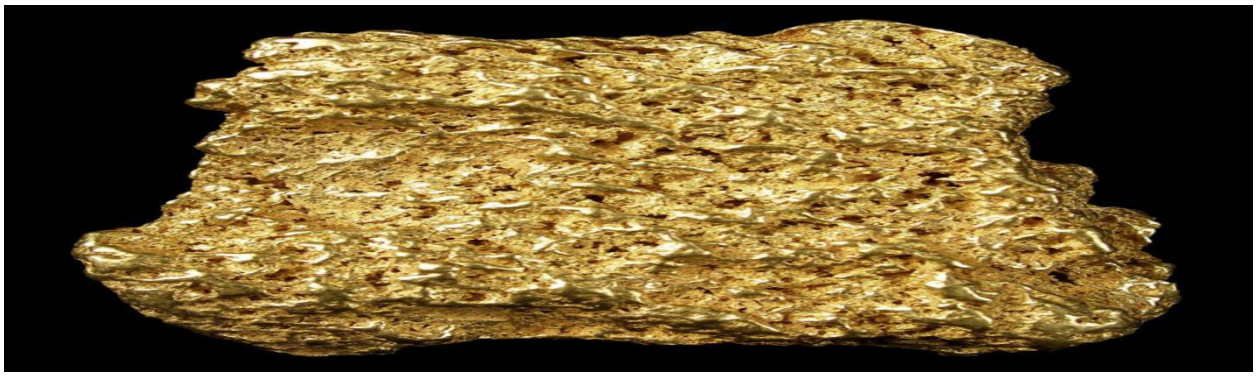


Fig No .12 Gold

Source:https://upload.wikimedia.org/wikipedia/commons/7/73/Gold-34559.jpg

(ii) **Ferrous metals:** Metallic minerals containing iron are called ferrous metals. Other metals are often mixed with iron to produce various kinds of steel. Ferrous minerals are crucial in the development of metallurgical industries. Examples of ferrous metals are iron ore, hematite and magnetite.

Fig No. 13 Hamatite

Source:https://upload.wikimedia.org/wikipedia/commons/1/13/Hematite_grise_terrestre.jpg

(i) **Non-ferrous metals:** Metallic minerals not containing iron are called non-ferrous metals, which include metals like copper, bauxite, lead, zinc, tin, aluminium etc. These are more expensive than the ferrous metallic minerals. Non-ferrous metal have higher conductivity, are non-magnetic and are resistant to corrosion.

Fig No. 14 Bauxite

Source:https://upload.wikimedia.org/wikipedia/commons/thumb/4/40/Bauxit_Mineral.jpg/1280px-Bauxit_Mineral.jpg

Non-Metallic Minerals

These minerals do not have any metal content. They are non-malleable and non-ductile and

also not good conductors of heat and electricity. Sulphur, phosphates and nitrates are examples of non-metallic minerals. Cement is a mixture of non-metallic minerals. Mostly non-metallic minerals require no major alteration for use and thus they maintain their form and physical properties.

Fig No .15 Sulphur

Source : https://upload.wikimedia.org/wikipedia/commons/4/4e/Sulphur-155884.jpg

Difference between metallic and non-metallic minerals:

1. Metallic minerals can be melted to get new products whereas non-metallic minerals cannot give products on melting.
2. Metallic minerals are usually found in igneous and metamorphic rocks whereas non-metallic minerals are found in sedimentary rocks.
3. Metallic minerals are hard and have specific lustre, whereas non-metallic minerals are not so hard and do not have specific lustre.
4. Metallic minerals are malleable and ductile whereas non-metallic minerals are non-malleable and non-ductile.
5. Metallic minerals do not break when hit whereas non-metallic minerals may get shattered into pieces.

Rocks

Throughout history, rocks have been used by human beings, for making fire, hunting and food gathering and for agriculture. The earth's crust is composed of different types of rocks. Rocks are composed of grains of minerals. The types of rocks and the presence of minerals in them are decided by the manner in which they were formed. A rock is an aggregate of one or more minerals. It may be hard or soft and of varied colours. For example, granite is hard,

soapstone is soft. Gabbro is black and quartzite can be milky white. Rocks do not have a definite composition. Feldspar and quartz are the most common minerals found in rocks.

Fig no .16 Rock outcrop along a mountain creek near Orosí, Costa Rica

Source ; https://upload.wikimedia.org/wikipedia/commons/7/72/DirkvdM_rocks.jp

Petrology is the science of rocks. A petrologist studies rocks in all their aspects viz., mineral composition, texture, structure, origin, occurrence, alteration and relationship with other rocks.

Classification of Rocks

As there is a close relation between rocks and landforms and soils, a geographer requires basic knowledge of rocks. There are many different kinds of rocks, which are grouped under three families based on their mode of formation. They are:

i. *Igneous Rocks* — solidified from magma or lava;
ii. *Sedimentary Rocks* — the result of deposition of fragments of rocks by exogenous processes;
iii. *Metamorphic Rocks* — formed out of existing rocks undergoing recrystallization.

Igneous Rocks

As igneous rocks form out of magma or lava from the interior of the earth, they are known as primary rocks. They are mostly crystalline and are made up of interlocking crystals. Formation of igneous rocks: Igneous rocks (Ignis – in Latin means ‘Fire’) are formed when magma cools and solidifies. You already know what magma is. When magma cools as it moves upward and turns into solid form, it is called igneous rock. The process of cooling and solidification can happen in the earth’s crust or on the surface of the earth. There are some reasons behind melting of rocks such as increase in temperature or change in composition.

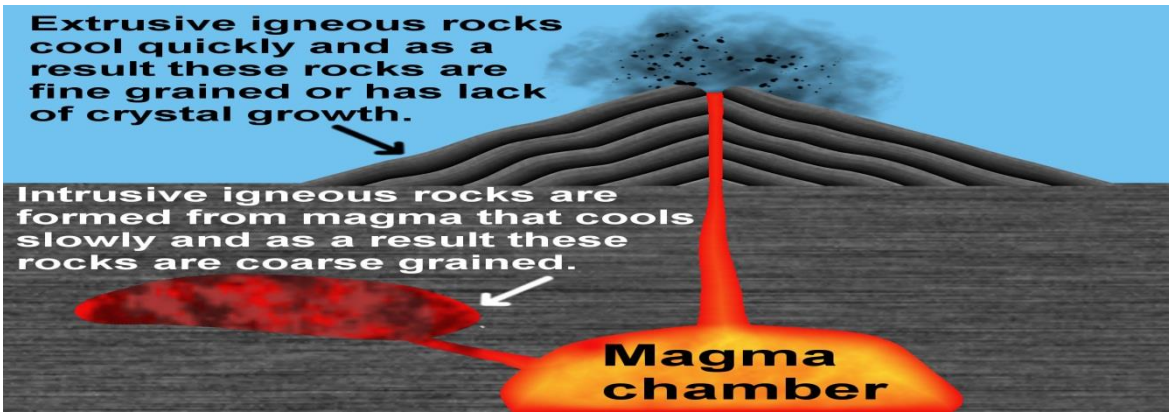


Fig No 17. Forming of Igneous rock

Source:https://en.wikipedia.org/wiki/Igneous_rock#/media/File:Igneous_rock_eng_text.jpg

Classification of igneous rocks:

These rocks are of two basic types

1) *Intrusive* or plutonic igneous rocks and

2) *Extrusive* or volcanic igneous rocks.

Intrusive igneous rocks are formed below the earth's surface and the slow cooling of magma there allows form atom of large crystals gabbro and basalt rocks and coarse-grained.

Fig No. 18. Granite (an intrusive igneous rock) exposed in Chennai

Source:https://en.wikipedia.org/wiki/Igneous_rock#/media/File:IndianGranite.jpg

Extrusive igneous rocks are formed on the earth's surface where they form small crystals as they cool quickly; basalt and andesite are examples of extrusive igneous rocks.

Fig No.19 Extrusive igneous rock is made from lava released by volcanoes

Source:https://en.wikipedia.org/wiki/Igneous_rock#/media/File:Volcano_q.jpg

Igneous rocks can also be classified on the basis texture. Texture depends upon size and arrangement of grains or other physical conditions of the materials. If molten material is cooled slowly at great depths, mineral grains may be very large. Sudden cooling (at the surface) results in small and smooth grains. Intermediate conditions of cooling result in intermediate sizes of grains making up igneous rocks. Granite, gabbro, pegmatite, basalt, volcanic breccia and tuff are some examples of igneous rocks.

Fig No .20 Gabbro specimen showing phaneritic texture; Rock Creek Canyon, eastern Sierra Nevada, California.

Source:https://en.wikipedia.org/wiki/Igneous_rock#/media/File:GabbroRockCreek1.jpg

https://en.wikipedia.org/wiki/Igneous_rock#/media/File:GabbroRockCreek1.jpg

Geological significance of igneous rocks: About 90% of the top 16 km of the earth's crust is formed of igneous and metamorphic rocks. Igneous rocks are geologically very important because:

1. They give us information about the composition of mantle
2. They are helpful in comparing adjacent geological strata as absolute age can be obtained by radiometric dating.
3. Because of their features, they allow tectonic reconstitutions.

Sedimentary Rocks

The word 'sedimentary' is derived from the Latin word sedimentum, which means settling. Rocks (igneous, sedimentary and metamorphic) of the earth's surface are exposed to denudational agents, and are broken into fragments of various sizes. Such fragments are transported by different exogenous agencies and deposited elsewhere. These deposits may be compacted into rocks. This process is called **lithification.** In many sedimentary rocks, the layers of deposits retain their characteristics even after lithification. Hence, we see a number of layers of varying thickness in sedimentary rocks like sandstone, shale etc.

Fig No.21 Sedimentary rock with sandstone in Malta

Source:https://en.wikipedia.org/wiki/Sedimentary_rock#/media/File:Sedimentgesteine_auf_Malta.JPG

A number of such as climate, relief, presence of different agents of deposition, decide the rate of deposition of sediments.. Only 7.9% of the earth's crust in its total volume is formed by sedimentary rocks of which 82% are shales, and 6% sandstone etc. these sedimentary rocks often contain fossils.

Depending upon the mode of formation, sedimentary rocks are classified into three major groups: (i) mechanically formed — sandstone, conglomerate, limestone, shale, loess etc. are examples; (ii) organically formed— geyserite, chalk, limestone, coal etc. are some examples; (iii) chemically formed — chalk, limestone, halite, potash etc. are some examples.

Sedimentary rocks are of great economic value:

1. They contain major energy resources like coal, natural gas etc. are formed.
2. They are used for building stone, plaster cement and fertiliser etc.

Fig No.22 Cross-bedding in a fluviatile sandstone, Middle Old Red Sandstone (Devonian) on Bressay, Shetland Islands

Source:https://en.wikipedia.org/wiki/Sedimentary_rock#/media/File:Crossbeddingbressay.jpg

Metamorphic Rocks

The word metamorphic means 'change of form'. These rocks form due to of pressure, volume and temperature (PVT) changes. Metamorphism is the process through which any type of rock is changes its physical and chemical Properties. The original rock is called protolithic. which, it may be igneous, sedimentary or metamorphic rock. In the process of metamorphism, the protolithic is subjected to heat. Temperature above (more than 150 degree Celsius) and high pressure (about 1500 bars).

Fig No.23 Quartzite, a type of metamorphic rock

Source ; https://en.wikipedia.org/wiki/Metamorphic_rock#/media/File:Quartzite.jpg

Metamorphism occurs when rocks are forced down to lower levels by tectonic processes or when molten magma rising through the crust comes in contact with crustal rocks or underlying rocks are subjected to great amounts of pressure by overlying rocks. Metamorphism is a process by which already consolidated rocks undergo recrystallization and reorganisation of materials within original rocks. Some examples of the metamorphic rocks are slate, marble, schist, quartzite and gneiss.

Types of metamorphism

1. **Dynamic metamorphism:** Mechanical disruption and reorganisation of the original minerals within rocks due to breaking and crushing without any appreciable chemical changes is called dynamic metamorphism.

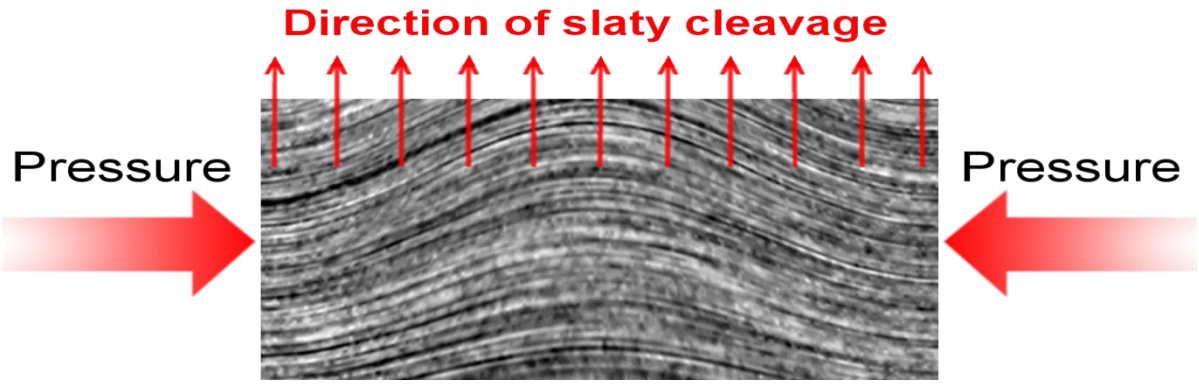


Fig No .24 Dynamic Metamorphism

Source:https://upload.wikimedia.org/wikipedia/commons/d/d6/Dynamo_metamorf_eng_text.png

2. **Thermal metamorphism:** The materials of rocks chemically alter and recrystallize due to thermal metamorphism. Thermal metamorphism can be further grouped into two —

a) Contact metamorphism and b) regional metamorphism.

In **contact metamorphism,** the rocks come in contact with hot intruding magma and lava and the rock materials recrystallize under high temperatures. Quite often new materials form out of magma or lava added to the rocks.

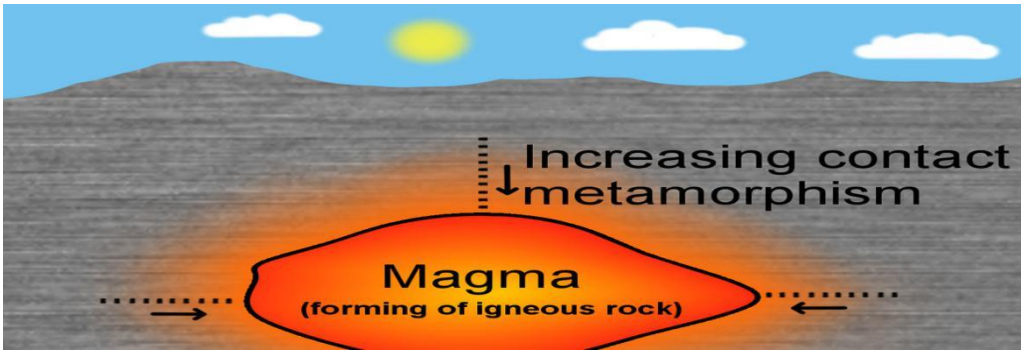


Fig. No.25 Contact metamorphic

Source:https://en.wikipedia.org/wiki/Metamorphic_rock#/media/File:Rock_contact_metamorphism_eng_big_text.jpg

In **regional metamorphism**, rocks undergo recrystallization due to deformation caused by tectonic shearing together with high temperature or pressure or both.

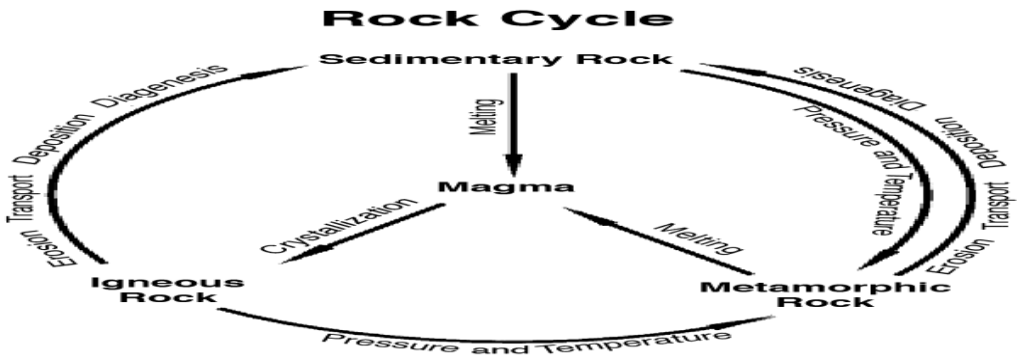
In the process of metamorphism in some rocks, grains or minerals get arranged in layers or lines. Such an arrangement of minerals or grains in metamorphic rocks is called **foliation or lineation**. Sometimes minerals or materials of different groups are arranged into alternating thin to thick layers appearing in light and dark shades. Such a structure in metamorphic rocks is called banding and rocks displaying banding are called banded rocks. Types of metamorphic rocks depend upon the properties of original rocks that were subjected to metamorphism. Metamorphic rocks are classified into two major groups — foliated rocks and non-foliated rocks.

Importance of Metamorphic Rocks:

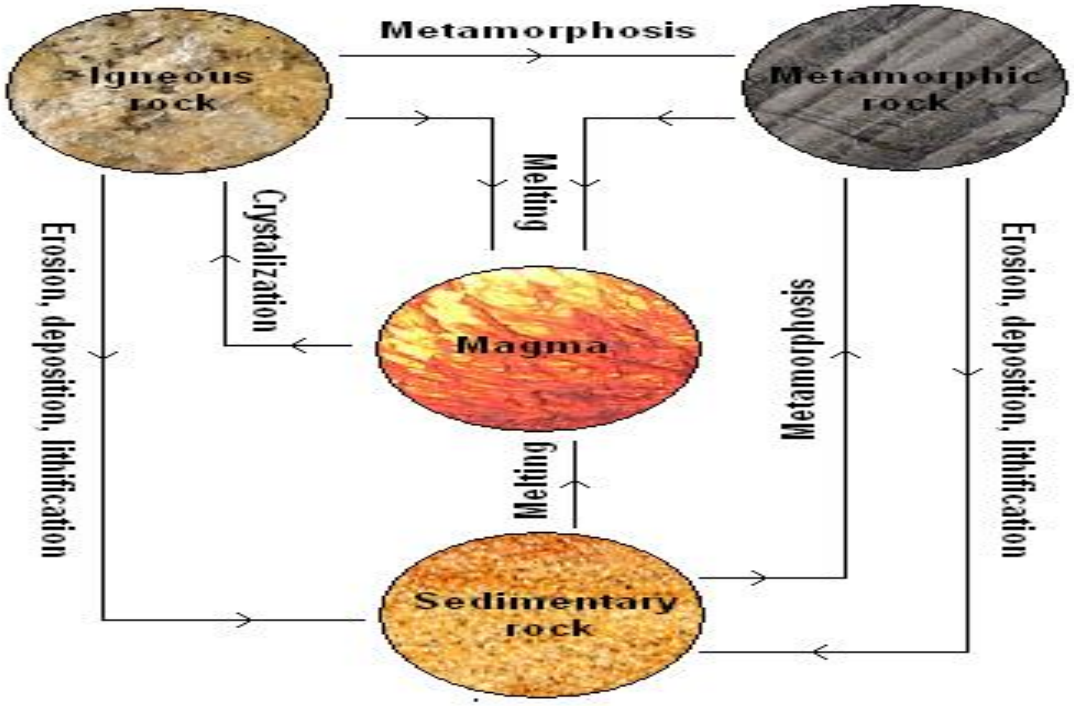
a) Their study gives us information about the temperature and pressure conditions at greater depth within the earth's crust.
b) They help in identifying areas where dynamic processes are more active because in these areas metamorphic processes are more intense. These may be volcanically or seismically active areas.
c) They can be used in making buildings and roofs.

Rock Cycle

Rocks do not remain in their original form for long but may undergo transformation. Rocks are also created and destroyed in cycles. A rock cycle is a continuous process that describes the formation, breakdown and reformation of rocks, through which old rocks are transformed into new ones. The rock cycle explains how the three types of rocks (igneous, sedimentary and metamorphic rocks) are related to each other and how the earth processes change a rock from one type to another. Plate tectonic movement is the most important driving force behind the rock cycle.



Source:https://upload.wikimedia.org/wikipedia/commons/6/6b/Rock_cycle.gif



Source:https://upload.wikimedia.org/wikipedia/commons/4/4f/Rock_cycle_illustration.PNG

Igneous rocks are primary rocks and other rocks (sedimentary and metamorphic) form from these primary rocks. Igneous rocks can be changed into metamorphic rocks. The fragments derived out of igneous and metamorphic rocks form into sedimentary rocks. Sedimentary rocks themselves can turn into fragments and the fragments can be a source for formation of sedimentary rocks. The crustal rocks (igneous, metamorphic and sedimentary) once formed, may be carried down into the mantle (interior of the earth) through subsduction the process of (parts or whole of crustal plates going down under another plate in zones of plate convergence) and the melt due to increase in temperature in the interior and turn into molten magma, the original source for igneous rocks.

Summary

- Earth's crust is composed of eight elements.
- Minerals and rocks are play a very important role in shaping the earth surface.
- The intense heat and pressure inside the earth surface is the force that drwes the rock cycle that leads to the continues creation and deformation of rocks.