Northern Technical University (NTU)
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Surveying Engineering Department

1st Stage
Geology

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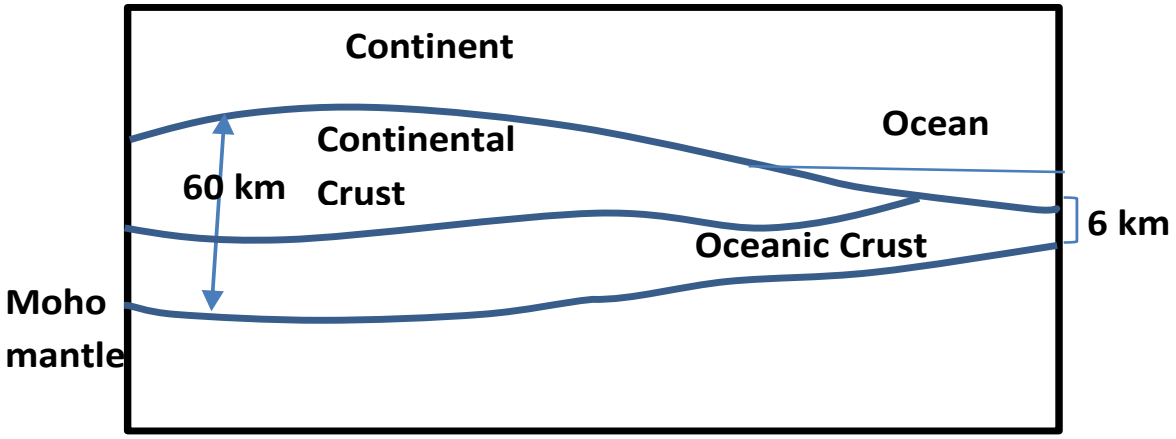
The structure of the Earth : المحاضرة الثانية

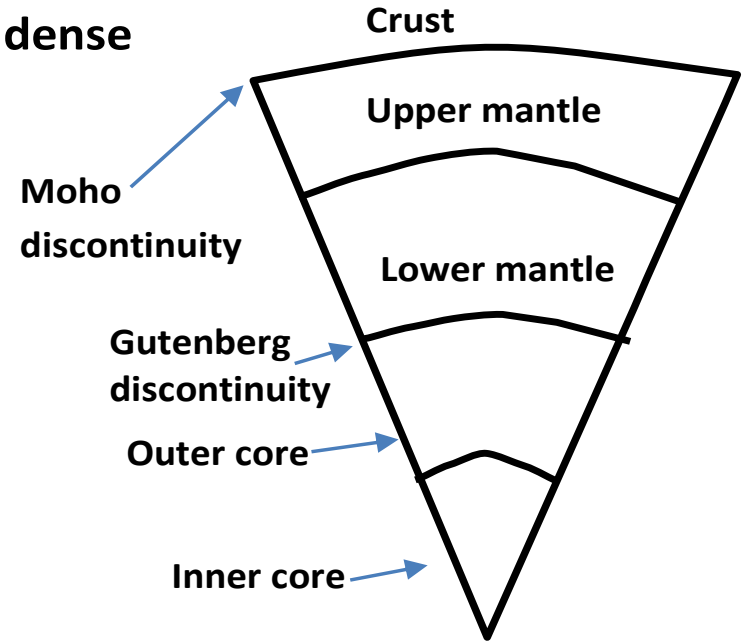
The Earth that we see is largely solid , the solid earth is made up of rocks which in turn are made of simple units called minerals .

The earth is divided to three parts: as in figure (1) Section through the earth

1- Crust

The part of the earth above the Mohorovicic discontinuity It is less dense than the mantle the continental crust of the great and areas is thicker , less dense and older than the oceanic crust





it is essential to understand that the crust beneath the continents is very different in both composition and thickness from the crust beneath the ocean floors.

١. **Felsic rock** forms the upper part of the continental crust in a layer with an average thickness of perhaps (16km) this felsic rock is containing silica and alumina called sail and can also be described as granitic rock.

٢. **The mafic rock** form the oceanic crust or represent the lower part of continental crust Largely of the composition of basalt and can be described as basaltic rock .

Mantle: The part of the earth between the crust and the core or between the moho and the Gutenberg discontinuity.

Mohorovic discontinuity / a boundary that separates the crust above from the mantle below, the moho is at depth of about 20-40 km below the surface of the continents and about (10)km below ocean floor there is a difference between the velocities of earthquake wave above and below the moho.

- at the base of the basaltic layer there is an abrupt change to a denser mantle rock which we interpret to be ultra-mafic rock with a composition resembling Dunite.

- the surface of abrupt change form mafic to ultramafic rock is known as the moho discontinuity.

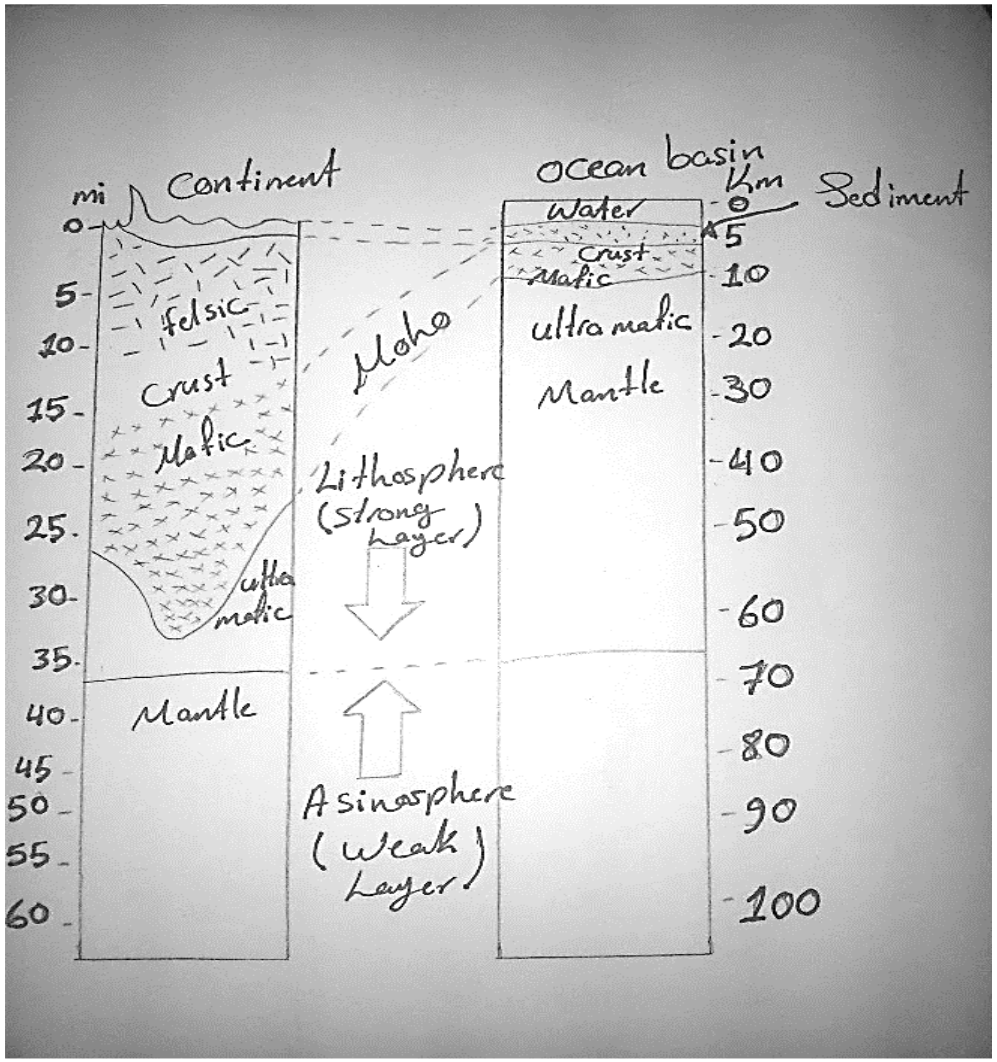
The upper part of mantle is composed from strong layer as well as the above crust called Lithosphere (the outer solid part of earth ,the crust and upper part of mantle to a depth 100km ,the Lithosphere is stiffer than the Asthenosphere , in the mantle after 200 km ,the rock is being soft because of the temperature is very close to its melting point , this layer called Asthenosphere .

Asthenosphere/ the part of the mantle from a depth of about (100km) to 250-300km it is not as strong and stiff as the lithosphere .

Mesosphere / the part of the mantle below the asthenosphere from a depth of 250-300 km to the core .

Gutenberg discontinuity / a boundary that separates the mantle from the core at a depth of about (2900km) below the earth's surface ,the velocities of earth waves are different above and below the Gutenberg discontinuity .

Core / the central part of the Earth below the Gutenberg discontinuity at depth of about 2900 km below the earth's surface ,the core is thought to consist almost entirely of iron mixed with some Nickel . It can be divided in to the outer core. which may be liquid ,and the inner core ,which may be solid at a depth of 5100km, the density of the core is more than the twice the density of the mantle.



Comparison of the crust and mantle under continent and ocean basins

In the detailed composition of the earth's crust , it is element have combined to from minerals .

The 10 most abundant elements in the earth's crust .

Symbol	name	Weight %
O	Oxygen	46.60
Si	Silicon	27.72
Ai	Aluminum	8.13
Fe	Iron	5.00
Ca	Catenin	3.63
Na	Sodium	2.83
K	Potassium	2.59
Mg	Magnesium	2.09
Ti	Titanium	0.44
H	Hydrogen	0.14

Crystals and minerals المحاضرة الثالثة

A body with surface that are smooth ,flat and regular arranged ,the regular shape of a Crystal results from the regular arrangement of the atoms of which it is made

-Crystal lattice : the regular arrangement of atoms in three dimensions in a crystalline solid .

-unit cell : The smallest complete Pease of a crystal lattice that shows the arrangement of the atoms in a crystal , the unit cell contains a number of atoms arranged in a regular way .it is repeated in three dimensions to from the crystal lattice

Face : a single flat surface on crystal in crystallography ,it is not the sizes of faces that are important but the angles between them called the interfacial angles .

-Form : a form is a group of crystal face that are related to a single face by the symmetry elements of a particular crystal class ,for example ,eight face makes up pyramid form in the cubic or tetragonal system ,the term crystalline implies to a regular atomic structure. there is another class called crypto crystalline ,represent fine grained aggregates and their character is described under the microscope only.

- **Non crystalline** material is termed a amorphous which is rare among minerals (Opal mineral)

For reference purposes, the vertical crystallographic axis is Labelled (C), the left to right one(b)and the back to front one (a),faces are named according to which axes they cut .for example :

١. face cutting all three axes is termed (a pyramid). .

٢. cutting two horizontal axes and parallel to one vertical axis is termed (a prism).

٣. cutting one horizontal axis and parallel to one vertical and one horizontal axis is termed (a pinacoid).

The relative development of different faces controls the habit of a crystal for example , a flat crystal is termed tabulat While one that is elongated is termed prismatic.

The form developed in the cubic system are special and sometimes complex because of the high symmetry ; they are grew special names such as cube ;octahedron(8 face), rhombodeducohedron(12 face) ,pyritohedron(24 face) which are not used in other system.

Mineral : Substance having a definite chemical composition or a definite range of composition ,that has been formed naturally and occurs in the Earth's crust , Most minerals have a character of crystal form.

The physical properties of Minerals

١. **Color :** color is an obvious property it is one of reliable test . available, many minerals have a variety of colors .such as (Quartz) and Fluorite while very few minerals have constant color such as sulphur or malachite .

2. Streak : The color of the powdered mineral which is obtained by scratching the mineral on a piece of unglazed porcelain called a streak plat ,the streak may be the color as that of the mineral ,it may be colored but different from the color of the mineral .the mineral may be too hard to produce a streak (Hematite gives a reddish -brown streak ,Magnetite have a black one and cassiteribe no streak.

3. Hardness : The hardness of mineral is measured by its ability to make a marks on the surface of another mineral .the scale of hardness that is use is due to mohos : ranging from (1) talc to 10 diamond ,the surface of minerals with hardness of less than 6 1/2 can be marked with a knife ,minerals with a hardness of 2 1/2 or less can be marked with a finger -nail

١. talc 2. gypsum 3. calcite 4. fluorite 5.apatit

6. orthoclase 7.Quartz 8.Topaz 9.corundum 10.diamond

4. **Luster :** it depend on the intensity of light reflect from the surface of a mineral specimen .luster may be:

Adamantine as in Diamond .a

resinous like that of resin ,(opal) .b

c- pearly like that a pearl Talc

d- metallic like of metal (magnetite) ,Galena

e- Vitreous or glassy like glass (obsidian),Quartz

f- silky like that of silk .(gypsum)

g- greasy (Graphite)

h- dull like that of earth (Cassirite)

5. Cleavage : is the property of breaking along Clearly marked smooth planes which are parallel to-possible crystal faces (Cleavage)may be ;

a. Perfect(mica) : when the broken surface is very smooth

b. Imperfect : when the broken surface is not so smooth

c. Absent : is broken surface is irregular or difficult

6. Fracture : The nature of the broken surface in any direction other than the cleavage direction may be :-

a. Conchoidal /when showing concave surface

b. uneven /showing irregular surface

c. even /showing smooth surface

d. hackly/showing much irregularly surface

e. splintery /breaking in splinter like parts

7. Forms : a- Granular (grains) b- friable(Hematite)

c-Nodular d- Oolites e- Geoidal f- Reni -form

g- Lamellar h- Foliated i- Fibrous j- Dendritic

k-bladed (mica)

المحاضرة الاولى

Outline

- Geology Defined
- Branches of Geology :
- The relation between Geology and other Science
- (Relation between Geology and Surveying)
- Origin of the Erath and their occurant

المحاضرة الاولى

Geology Defined :

The word Geology has been derived from the Greek words , (Geo) meaning the earth and logy is meaning science .

Geology is the science of the earth; how it was formed , what it is made of, its history and the changes that take place on it and in it .

Branches of Geology :

The subject of Geology is divided on to several branches which are as follows

١. Physical Geology /it deals with the Geological processes which bring about changes in the crust

This includes:

a. **Structural or Tectonic Geology** :it deals with the different kinds of structures produced in the crust of the earth as the result of Tectonic movement

b. **Dynamical Geology**: this deals with the processes both inside and outside .

c. **Geomorphology** : This deal with surface features of the earth (Topography)

2-Mineralogy and Petrology / they deal with minerals and rocks respectively (minerals formation)and association ,analysis .

3-Historical Geology /it deals with the past history of the earth ,the chronology of events which occurred on the surface of earth.

The evolutionary history of the earth as well as the animals and plants which lived on earth at different periods :

it includes the study :

a-Stratigraphy /dealing with the succession of rock formation

b-paleontology /dealing with the relics of ancient animals and plants called fossils

4-Economic Geology/ it deals with the study of useful minerals and rocks, and application of the knowledge of geology in prospecting for these economic deposits .

5-Engineering Geology /the knowledge of Geology has also been used in some cases of Engineering problems (selection of sites for Dams, railway, mining ,ground water prospecting .

Further the Science of Geology is interwined with some sister Sciences to form composite ones , such as Geophysics (based on Geology and physics mainly)and Geochemistry (based on geology and chemistry mainly) Geophysics is important in depicting the underground structures and Geochemistry is important for exploration of economic minerals .

The relation between Geology and other Science

the geology is application sciences which use physical theories and mathematics ,chemistry equation to solve pure geological problems for example :-

1-Geophysics (Geology and physics) from its methods of study has proved very useful in depicting the underground structures of area.

2-Geochemistry (geology and chemist)is important for using its processes in exploration for economic minerals and rocks.

3-Paleontology (based on geology and Biology) is important in study the history of the earth by using the fossils

4-Geomorphology (geology and Geography) it deals with the configuration of the earth (mountain and valleys) .

-using of isotope in geology is useful in determention the age of rock and deposits.

5-Engineering Geology it deal with engineering and geological properties of rocks and deposits and their application in building, mining ,Dames .

6-Petroleum Geology (relation between geology and engineering of petroleum in drilling oil boreholes and estimation the specific weight of oil .

(Relation between Geology and Surveying)

The Surveying processes is deal with distance and angles of points and drawing maps and sections and determination the elevation of points above or down of plane .

-Therefore the Surveying man needs information and knowledge about the deposits type and distinguished them in field ,and using the different Symbols of Lithology during the preparation of maps .

-Geomorphology (Topography)

-The Surveying needs some knowledge about geological fields such as engineering geology in building ,mining ,Dams which need detail surveying .

Origin of the Erath and their occurant

The earth being a member of the solar system .The origin of it is connected with that of the solar system there are many ideas to account for the origin of solar system .

Kant hypothesis: Kant proposed that the different parts of nebula, out of which the solar system was originated ,at first moved in different direction at different speed ,at time this nebula became a hot spinning and began radiate heat ,Gradual increase in the rate of revolution due to gradual contraction caused the separation of several rings from equatorial region and these rings in time condensed be from Planets , Meteorites.

Rocks المحاضرة الرابعة

Rocks can be broadly divided in to three main classes:

١. Igneous 2. Sedimentary 3. Metamorphic

Rocks /are naturally occurring aggregate of minerals and are units from which the earth's Crust is composed.

(Igneous Rock)

The word igneous is derived from the Latin word ignes meaning fire.

-The molten rock material together with the gas content is called magma.

The igneous rocks are formed from the solidification of magma.

Characters of Igneous Rocks:

Such rocks originate generally at depth but sometimes are formed on the crust of the earth .therefore there have two distinct

Classes of igneous rocks : 1-plutonic(Intrusive) or abyssal 2-Volcanic (extrusive)

Plutonic rocks : are those which have solidified at some depth below the surface of the earth .they ١. are seen only after long continued deep erosion ,the environment and condition under which plutonic rocks solidify are quite different from those under which volcanic rocks solidify .

During the Crystallization of plutonic rock pressure act and therefore the rate of cooling is slow and dissolved gases cannot escape ,this produces a coarse grained or phaneritic texture.

2. Volcanic rocks : rocks formed on the crust of the earth ,there is no effect of pressure and the gases also escape easily this produces a high rate of crystallization and consequent fine grained or aphanitic texture.

The demarcation line between these two group is not clear and commonly a third middle group is recognized ,these are the hypabyssal rocks :

Hypabyssal rocks : it is intermediate in its mode of origin between a plutonic and a volcanic rock ,its character is also intermediate between the two groups.

and which shows a medium grained texture.

Igneous rocks shows order of crystallization ,they present interlocking texture and massive and hard appearance ,they do not contain any fossils as the sedimentary rocks and nor any clear stratification ,the parallel arrangement of mineral peculiar to metamorphic rocks is also absent in the igneous rocks

One common order in which minerals crystallize from magma is shown in the diagram below, comprises two Series of minerals which crystallize independently of each other . If fractionation were to remove crystals in this order from basic magma, the earliest batches would form ultrabasic rocks , such as Peridotite , later batches would give Gabbro and Diorite and the final liquid residues would crystallize as a Granite.

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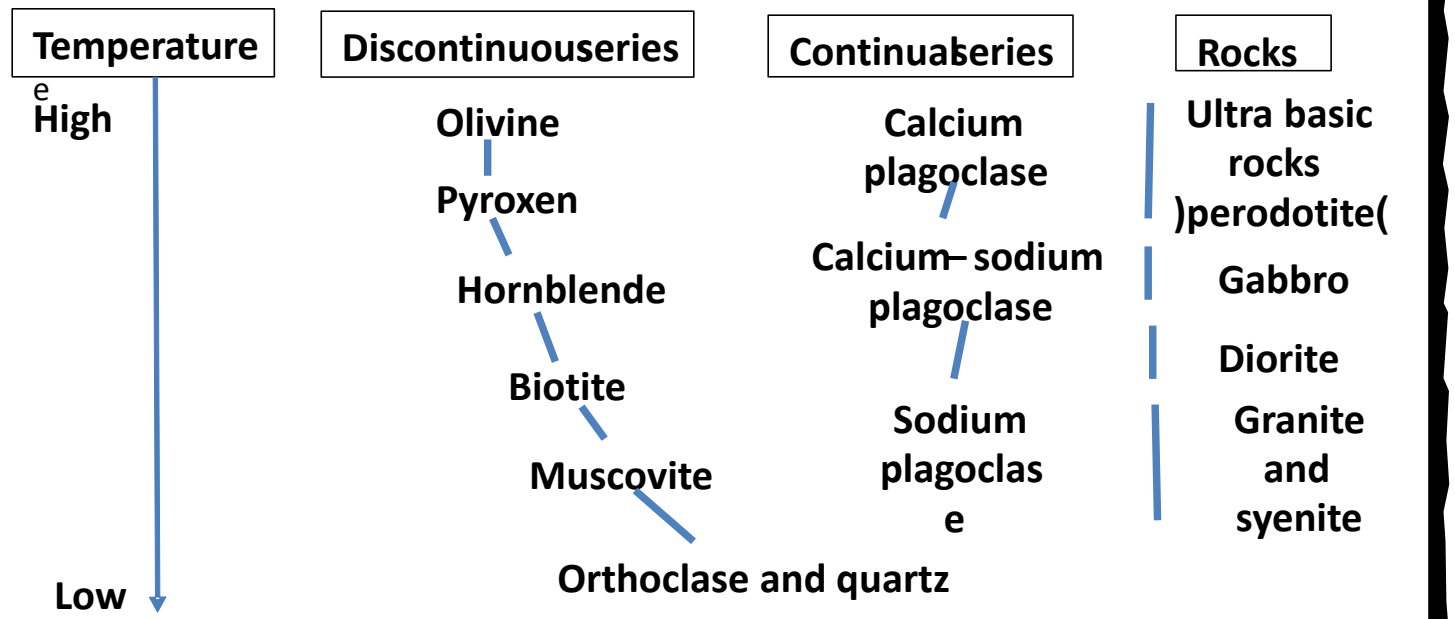


Order of crystallization of minerals from magma
)Bowens reaction series(

Common Igneous rocks :

1- Acidic (Silica more than 65%) :

Granite :- **It is medium to coarse - grained and light colored ,the silica percentage is quite high (65_80),this puts the rocks into the acidic group ,granite consist of quartz and Feldspar ,plagioclase may also be present ,Micas (muscovite and biotite)are frequent ,Accessory minerals include magnetite >Rhyolite is the volcanic equivalent of granite.** ١.

2. Pegmatite :- are of granitic composition ,during the last stage of crystallization of a magma the residual part are very rich in volatile matter ,Alkali and silica which produce big crystals ,commonly quartz ,orthoclase and mica are present and accessory minerals like apatite ,tourmaline topaz ,Lepidolite , beryle , cassiterite .etc....

2- Inter mediate (Silica 50-60%)

٣. **Syenite:** it is a medium to coarse -grained rock ,very similar to Granite ,minerlogically syenites do not contain quartz or very little of it ,the silica percentage is lower (50-60) or the Mica is abundant ,plagoclase is frequent ,and rare of pyroxene and hornblende Accessory minerals include nepheline ,Leucite ,apatite magnetite etc.

- **Trachyte** :is the volcanic equivalent of Syenite

4. **Diorite** : it is medium to coarse grained rock dark in colour ,is similar to syenite ,but the distinction between syenite and diorite in the alkali percentage is lower in diorite ,whereas the calcium and ferromagnesian mineral have greater percentage.orthoclase is absent while plagioclase is present ,and Biotite ;hornblende and pyroxene are also present . Dacite and Andesite are the volcanic equivalents.

Basic (silica 45-50%)

5. Gabbro : It is medium to coarse grained plutonic rock of dark colour and low silica percentage (40-50) Plagioclase and pyroxenes are important minerals in Gabbro ,Olivine is a common accessory mineral

6. Dolerite : it is the hypabyssal equivalent of the gabbro type .it is medium to fine grained ,have the composition of Gabbro .

7. Basalt : it is the volcanic equivalent of the Gabbro ,it is the most common volcanic rock Basalt is fine grained and dark in colour .it contain lime -rich plagioclase and pyroxene as primary minerals and accessory minerals include olivine ,sphere , ilmenite , leucite ,nepheline etc.

Ultra basic (silica less than 45%)

8. Peridotite: it is a coarse grained rock of dark color, it is very basic rock, consist of Ferromagnesian minerals, mainly pyroxenes, olivine and hornblende accessory minerals inclued, ilmenite, garnet, chromite sphere etc.

Table 6–2. Classification of igneous rocks

	Composition				
Texture	*Felsic*	*Intermediate*	*Mafic*	*Ultramafic*	*Mode of Emplacement*
Glassy	Obsidian Pumice	—	Basalt Glass	—	Extrusive
Aphanitic	Rhyolite[1] Felsite[2]	Andesite	Basalt	—	Extrusive
Aphanitic porphyritic	Rhyolite porphyry[1] Felsite porphyry[2]	Andesite porphyry	Basalt porphyry	—	Extrusive
Phaneritic	Granite	Diorite	Gabbro	Dunite Peridotite	Intrusive
Phaneritic porphyritic	Granite porphyry	Diorite porphyry	Gabbro porphyry	—	Intrusive
Fragmental		Tuff, volcanic breccia[3]			Extrusive

[1] Quartz visible.
[2] Quartz not visible.
[3] Fragmental rocks may have a composition ranging from felsic to mafic.

Sedimentary Rocks

المحاضرة الخامسة

Sedimentary rocks are those rocks which have been derived from the consolidation of sediments .these sediment are the products of erosion both mechanical and chemical from some pre-existing rock masses ,the sediments are carried both in suspension as well as in solution and are deposited in basins like lakes and more commonly in seas and oceans ,in the case of marine deposit, remains of marine animals and plants also contribute to the accumulating mass ,the consolidation of the materials by pressure or by cementing materials like silica ,calcium carbonate ,iron oxide products hard rock called sedimentary rocks.

The sedimentary rocks can classify in two groups in depending on origins of the sediment constituting the rock:

١. Clastic 2- Non clastic

١. **Clastic sediment** :consists of particles broken away individually from a parent rock source, subdivided into groups

1-Pyroclastic sediments ,this material called tephra.

١. **Detrital sediments** : mineral fragment's derived by the weathering of pre-existing rocks of any classification.

2. Non Clastic sediment : include two subdivisions:

١. **Chemical precipitates** :are inorganic compounds precipitate from a water solution in which that matter has been transported.

٢. **Organically derived sediments** : consists of both the remains of plants or animals and mineral matter produced by the activates of plants and animals for examples ,the shell matter secreted by animals ,which is true mineral.

The detrital sediments :

The most abundant particles of detrital sedimentary rocks consist of quartz, rock fragments, feldspar and clay minerals in addition to these minerals there is durable minerals which

which are highly resistant to physical abrasion and chemical alteration, because of their greater density, are compared with Quartz and called heavy minerals for example is magnetite ,oxide of iron.

The naming of clastic Rock depends on the sizes ,the widely accepted scale is the went worth scale :

Grate name	Diameter
Boulders	Cover 256
Cobbles	64-256
Pebbles	2-64
Sand	0.66-2
Silt	0.004-0.06
Clay	Under 0.004

(Went worth scale)

The clastic Rocks :

١. **Sedimentary Breccia:** consist of large angular blocks in a matrix of finer fragments, these rocks represent ancient submarine landslides.

٢. **Volcanic Breccia** : is the equivalent rock in the pyroclastic group

٣. **Conglomerate:** consist of pebbles or pebbles, usually well rounded in shape, embedded in a fine grained matrix of sand or silt.

٤. **Sand stone** : composed of grains in the range from 2mm.to 0.06 mm. mainly composed of quartz and some heavy mineral and muscovite mica ,this particles may be cemented by silica the Products rock is hard rock with great resistance of weathering and erosion or cemented by calcium carbonate .

The sand stone types :

.a **Gray Wack** : is gray in colour ,composed of Quartz .and feldspar ,Ferro -magnesia minerals .which has been derived from some basic igneous rocks or argillaceous Rocks

.b **Grit** : is sandstone with coars grain and angular.

.c **Arkose**: it is sand stone with percentage of fled spare (orthoclase) more or less resembling granite is pink in colour.

5. Silt stone : the compaction and cementation of layers of silt materials give a compact fine grained rock the consisting materials have bigger size than shale and mud stone.

6. Clay stone : The consolidation of clay layer form clay stone

7. mud stone : The compaction of mixture of silt and clay form mudstone

8. Shale : is laminated mud and clay composition can easily break up in to small flakes and plates .

The Non clastic sediment :

The most important minerals of the non clastic. Sediments class are the Carbonates, are compounds of the calcium ion or magnesium ion, or both

Calcium carbonate is the composition of one of the most abundant and wide spread of minerals calcite and an important chemical precipitate is dolomite.

Evaporite: is chemical precipitates, these are highly soluble salts deposited from salt water bodies when evaporation is sustained under an arid climate the important mineral of evaporates.

1- **Halite ⇨ sodium Chloride**
2- **Anhydrite and Gypsum ⇨ Sulfate compounds calcium.**

- **Two mineral important in non clastic sediment :**

1- **Hematite ⇨ oxide of iron**

2- Chalcedony ⟹ a form of silica lacking obvious crystalline structure occur as nodules and layers is referred as chert.

The Non clastic Rocks :

١. **Limestone** : sedimentary deposit of calcium carbonate, this deposition is either from solution or from the remains of the dead bodies of plant or marine animals makes the formation of limestone rocks.

٢. **Chalk** : it is a soft and loose variety of limestone in which foraminifera shells are abundant

٣. **Coquina**: it is shelly limestone in which the shells of animals cover 90%

٤. **OoLitic limestone**: it is variety of limestone in which this small globules called oolite.

5.Marl: it is an impure variety of limestone containing besides calcium carbonate , amount of clayey material, marl sometimes are used as cementing material

6.Dolomite: This is a Variety which contains a good change to dolomites, the original calcium carbonates changes to carbonates of calcium and magnesium by the percolation of magnesium salt solutions The composition of dolomite is CaCo3MgCo3.

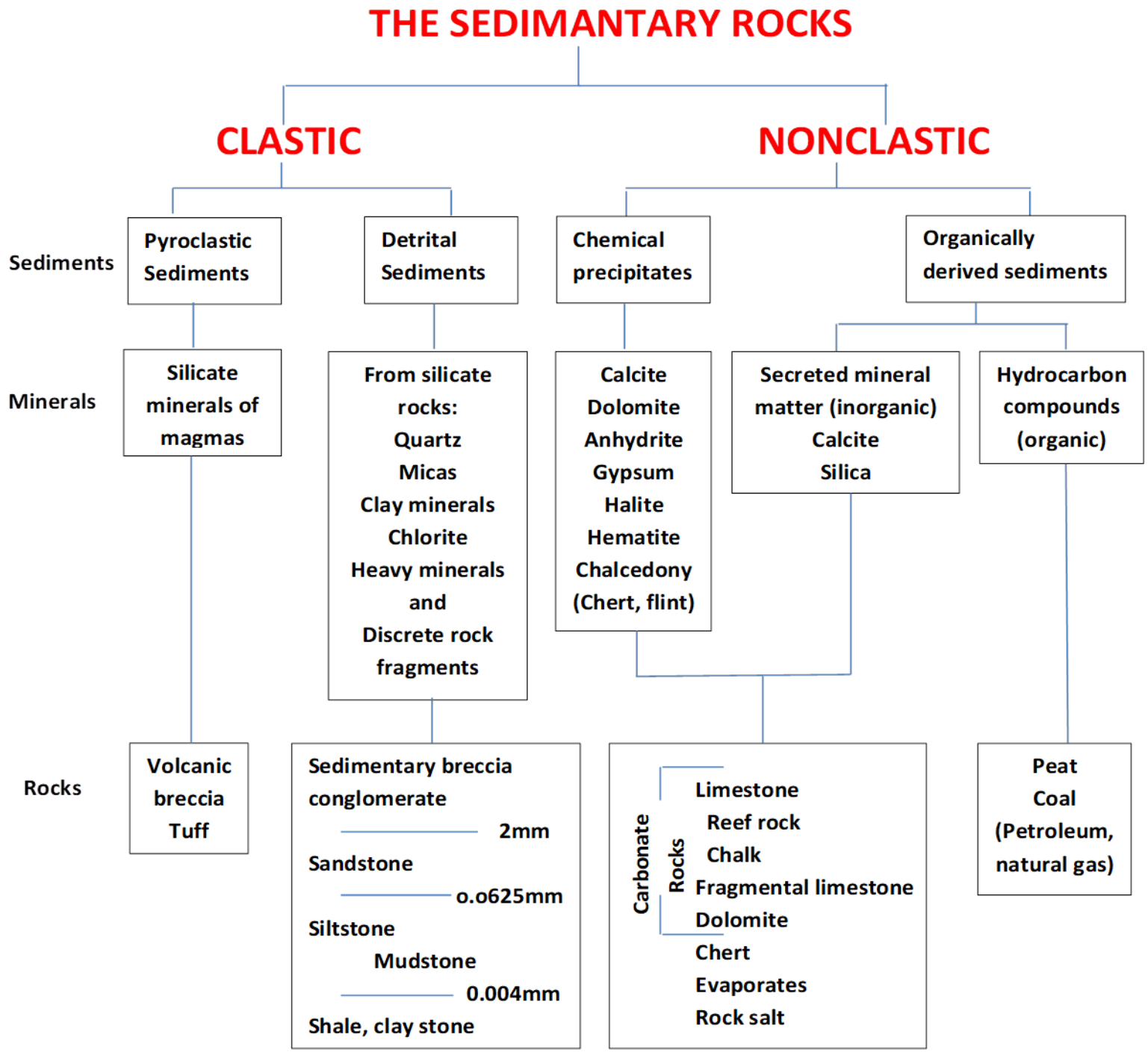
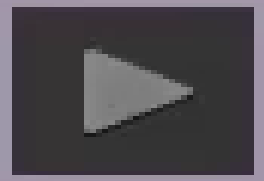


Figure 4.4 composition and classification of the sedimentary rocks .



Metamorphic Rocks

The word metamorphic or metamorphosed means changed

Metamorphism :-the processes by which rocks are changed by the action of heat or pressure or both the rocks changed by metamorphic ,The changes brought about by metamorphism are in the mineral composition ,texture or structure of the rocks .

-Changes that tack place at the Earth's surface (weathering or diagenesis)are not included under metamorphism.

- The metamorphic Rocks are derived from igneous Rock called ortho metamorphic rocks and those derived from sedimentary rock are called Para metamorphic rocks.

The work of heat pressure and chemical solutions is to produce some well-defined characters in metamorphic rocks -

- Metamorphic rocks are generally coarsely crystalline which distinguishes them from the sedimentary rocks

- there is some parallel arrangement of minerals (Foliation)which distinguishes them in metamorphic ,there are some minerals which are seen in metamorphic rocks ,the minerals are - kyanite , andalusite, sillimanite , Zoisite, wollastonite , staurolite etc.

Kinds of metamorphism

1. Regional 2. Contact 3. Cataclastic

Regional metamorphism: produced by heat and pressure affecting the rocks of a large area (thousands of square kilometers in extent), it is felt in two ways ; .١

1- original minerals recrystallize and new minerals are formed.

2- A new set of structures is imposed on the rock may replace or obliterate original bedding structures .

Regional metamorphism (dynamo thermal) has affected enormous bodies of rock within the root Zones of mountain chains of the alpine type ,the effects are seen today in surface rocks over large areas. The layered aspect in regional metamorphic rocks is called foliation .

2. **Contact metamorphism** :- when a hot igneous body intrudes cooler rocks, the intruded rocks are likely to be recrystallized as the cooling magma loses its heat to its surroundings .This is called contact metamorphism.

-The Zone of contact metamorphism surrounding an igneous body is called the contact aureole.

-The aureole may range from a few cm.to several km wide.

-The contact metamorphic rocks possess a less obvious foliation or not foliation at all, because little directional pressure is applied by this process.

3. **Cataclastic metamorphism**: the mechanical breaking up of a rock by dynamic metamorphism

- Movement along faults at depths of several kms.in the earth results in crushing and grinding of rocks along the fault ,Rocks affected in this way are subjected to intense pressure and heat derived from friction as a result the rocks are ground up .

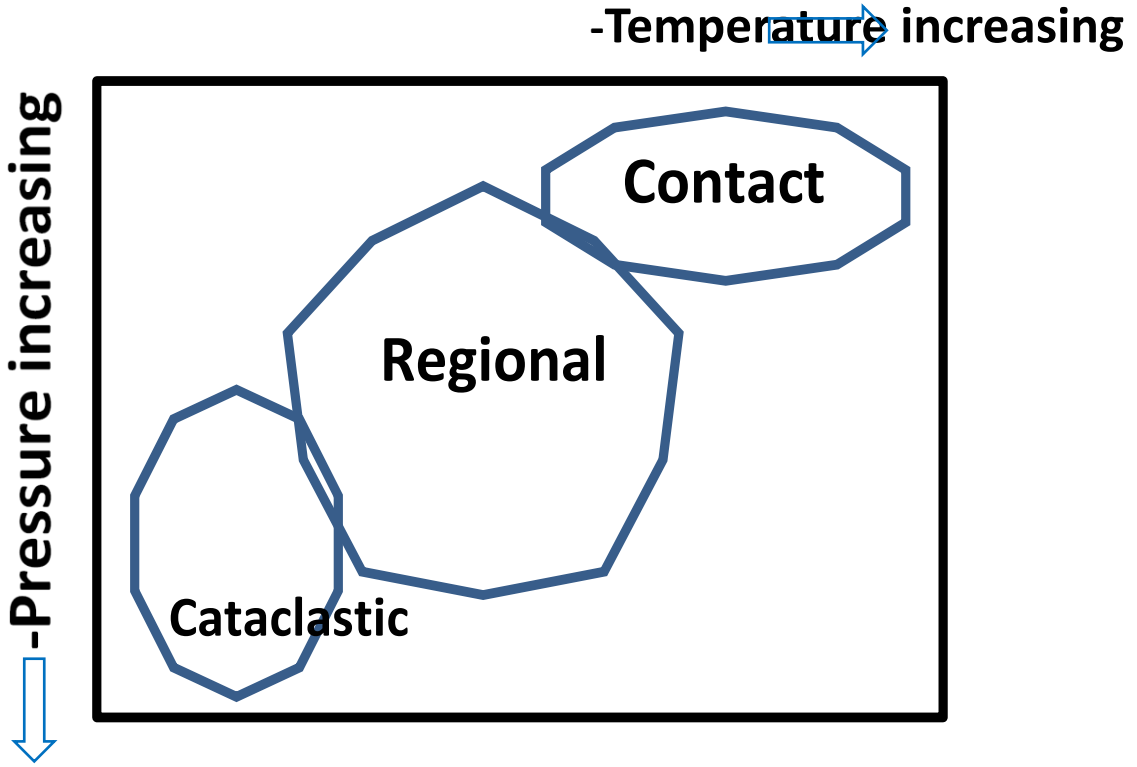

-Temperature increasing
-Pressure increasing
Contact
Regional
Cataclastic

Table 10-2 classification metamorphic rocks

	Rock type	Precursor	Metamorphic process
Foliated	Slate	Shale	Regional contact
	Phyllite	Volcanic rocks	Regional
	Schist	Impure sandstone	Regional
	Gneiss	Plutonic igneous rocks	Regional
	Amphibolite	Mafic igneous rocks Impure carbonate rocks	Regional
	Mylonite	Siliceous rocks	catalectic
	Phyllonite	Mica- and feldspar-rich rocks	catalectic
Nonfoliated	Quartzite	Sandstone	Regional contact
	Marble	Limestone dolostone	Regional contact
	Hornfels	shale	Contact

Metamorphic Rocks and their Classification Foliated rocks;

1-Slate : results from regional metamorphism of shale . and other fin-grained rocks (mudstone, some volcanic rocks),possess a marked foliation ,the rock (mudstone) breaks ,this breakage direction is called salty cleavage

2-Phyllite: is a foliated rock in which the micas have recrystallized to a greater extent than those in a slate it forms by recrystallization of slate. Foliation surface in phyllite have a more shiny appearance than those of a slate the clay-mica grains of slates have recrystallized to muscovite , biotitic or chlorite but remain fine grained .

3-Schist :in which mica and other minerals are completely recrystallized ,it is produced by regional metamorphism of phyllite ,and all major constituents of the rock should be visible to the unaided eye porphyrobiasts of garnet ,kynite ,staurotite and other minerals are common Instead of clays the micas muscovite and -Biotite and talc or chlorite may be the main constituent of this rock type.

4-Gneiss :in which different minerals may be segregated in to light and dark-colored bands Gneisses generally contain more feldspar and Quartz and fewer micas than schist ,results from high grade regional metamorphism of gray weak arkoses and other plutonic igneous rocks such as granite diorite ,syenibe Gneiss contain lenticular or eye shaped porphroblasts is called an aujen gneiss

5-Amphibolite: is produce from regional metamorphism of mafic igneous rocks (basalt ,gabbro)may or not passes marked foliation ,they are composed mainly from amphibole hornblende and contain other minerals Such as biotitic ,plagioclase ,calcite and quartz.

6-Mylonite: faintly to strongly banded fine grained rock formed by cataclastic metamorphism of other rocks ,mylonite very closely resembles the sedimentary rock (cherub)because of high quartz content It may contain large crystals or fragments of the coarser material from which it was derived .

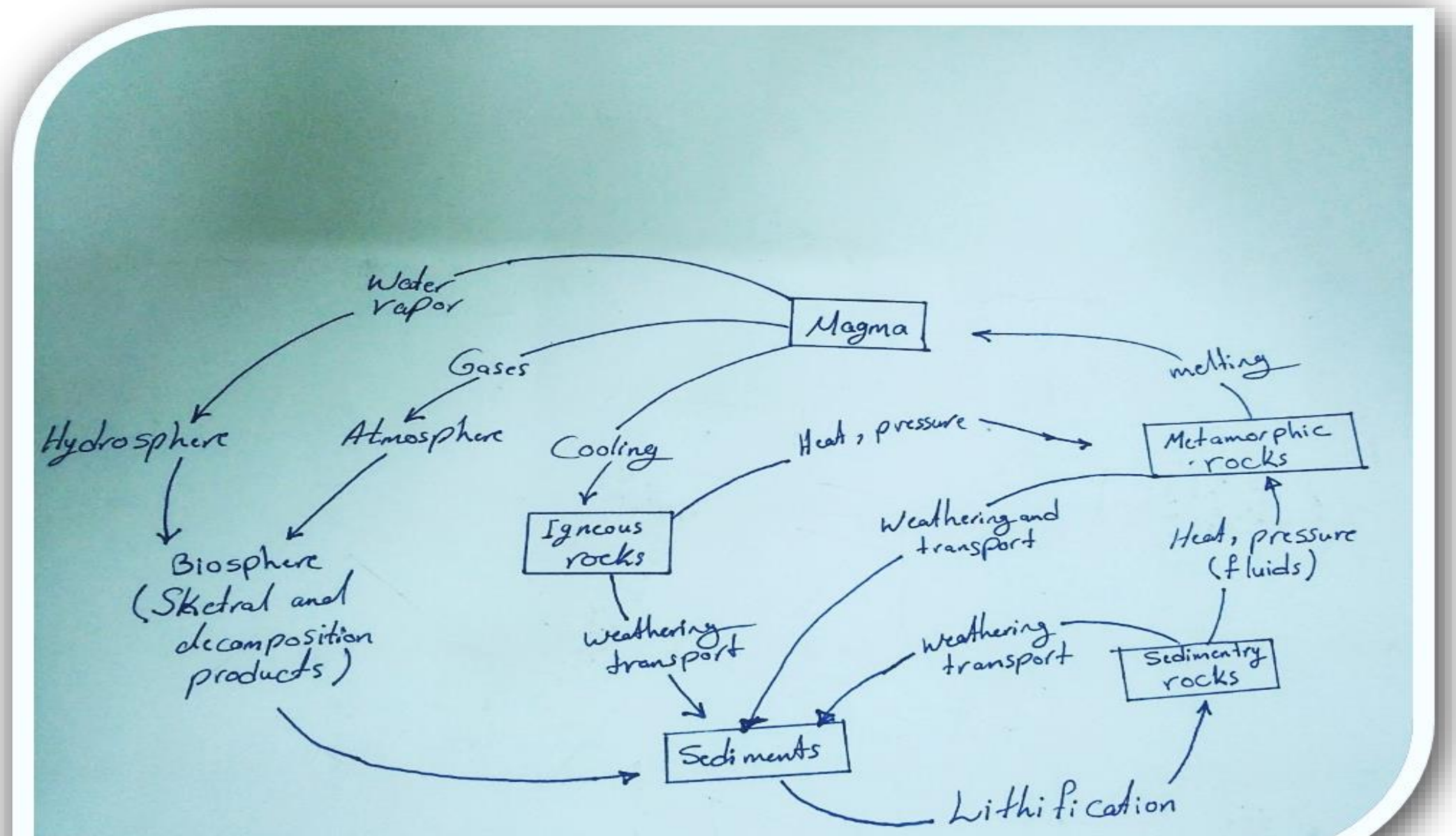
7-Phyllonite : is a strongly foliated mica -rich rock formed by cataclastic metamorphism of coarser feldspar or mucinous rocks ,micas are created from fled spare in Feld spathic rocks by cursing and reaction with water ,phyllonites closely resemble reaction but are not so common.

8-Quartzite : is produce from regional or contact metamorphism of sandstone sand grain are recrystallized and become welded to gather to produce Avery hard rock

9-Marble : produce by regional or contact metamorphism of limestone and goldstone, they may be fine to coarse grunted Although dark colored marbles exist most are of light color Crystals of garnet micas amphiboles ,pyroxenes ,talc and olivine appear during metamorphism of impure limestone

10-Hornfels : produced from contact metamorphism of fine grained clastic sedimentary rock (state), Hornfels is a gray fine grained ,contains porphroblasts of biotite or other minerals ,mainly composed of micas ,Quartz feldspar.

Rocks cycle in nature :-



Igneous , Sedimentary and metamorphic rocks are the products of different environments ,the rock melts form magma which later recrystallized in to igneous rocks originate at depths of 25 --200 km and temperatures of 1000c°,the minerals of rocks are stable at high temperatures .

Weathering of rocks exposed to the attack of atmosphere, water and organisms provides the row material of sediments, Running water glaciers and wind carry away the detritus and by erosion expose new surface to attack Eventually ,the weathering products come to rest in some low-lying land or in river lake or seen sea ,they are buried ,compacted Lithified ,the sedimentary rocks are formed within a temperature range of -30c°to 100c° ,the mineral of sedimentary rock are stable at these low temperatures and pressure .The igneous and sedimentary rocks later may be subjected to heat and pressure accompanying crustal movements .the effect of these is to change the character of the pre-existing rocks and in this way the metamorphic rocks result .

Metamorphic Rocks

The word metamorphic or metamorphosed means changed

Metamorphism :-the processes by which rocks are changed by the action of heat or pressure or both the rocks changed by metamorphic ,The changes brought about by metamorphism are in the mineral composition ,texture or structure of the rocks .

-Changes that tack place at the Earth's surface (weathering or diagenesis)are not included under metamorphism.

- The metamorphic Rocks are derived from igneous Rock called ortho metamorphic rocks and those derived from sedimentary rock are called Para metamorphic rocks.

The work of heat pressure and chemical solutions is to produce some well-defined characters in metamorphic rocks -

- Metamorphic rocks are generally coarsely crystalline which distinguishes them from the sedimentary rocks

- there is some parallel arrangement of minerals (Foliation)which distinguishes them in metamorphic ,there are some minerals which are seen in metamorphic rocks ,the minerals are - kyanite , andalusite, sillimanite , Zoisite, wollastonite , staurolite etc.

Kinds of metamorphism

1. Regional 2. Contact 3. Cataclastic

Regional metamorphism: produced by heat and pressure affecting the rocks of a large area (thousands of square kilometers in extent), it is felt in two ways ; .١

1- original minerals recrystallize and new minerals are formed.

2- A new set of structures is imposed on the rock may replace or obliterate original bedding structures .

Regional metamorphism (dynamo thermal) has affected enormous bodies of rock within the root Zones of mountain chains of the alpine type ,the effects are seen today in surface rocks over large areas. The layered aspect in regional metamorphic rocks is called foliation .

2. **Contact metamorphism** :- when a hot igneous body intrudes cooler rocks, the intruded rocks are likely to be recrystallized as the cooling magma loses its heat to its surroundings .This is called contact metamorphism.

-The Zone of contact metamorphism surrounding an igneous body is called the contact aureole.

-The aureole may range from a few cm.to several km wide.

-The contact metamorphic rocks possess a less obvious foliation or not foliation at all, because little directional pressure is applied by this process.

3. **Cataclastic metamorphism**: the mechanical breaking up of a rock by dynamic metamorphism

- Movement along faults at depths of several kms.in the earth results in crushing and grinding of rocks along the fault ,Rocks affected in this way are subjected to intense pressure and heat derived from friction as a result the rocks are ground up .

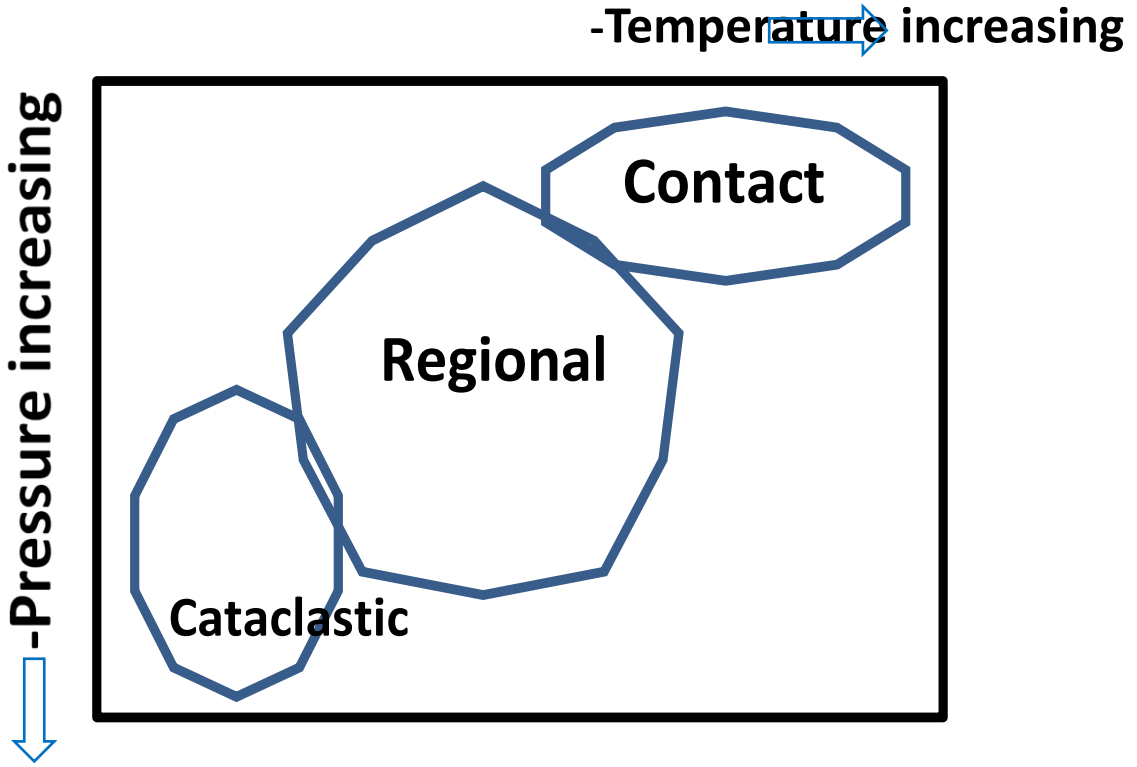

-Temperature increasing
-Pressure increasing
Contact
Regional
Cataclastic

Table 10-2 classification metamorphic rocks

	Rock type	Precursor	Metamorphic process
Foliated	Slate	Shale	Regional contact
	Phyllite	Volcanic rocks	Regional
	Schist	Impure sandstone	Regional
	Gneiss	Plutonic igneous rocks	Regional
	Amphibolite	Mafic igneous rocks Impure carbonate rocks	Regional
	Mylonite	Siliceous rocks	catalectic
	Phyllonite	Mica- and feldspar-rich rocks	catalectic
Nonfoliated	Quartzite	Sandstone	Regional contact
	Marble	Limestone dolostone	Regional contact
	Hornfels	shale	Contact

Metamorphic Rocks and their Classification Foliated rocks;

1-Slate : results from regional metamorphism of shale . and other fin-grained rocks (mudstone, some volcanic rocks),possess a marked foliation ,the rock (mudstone) breaks ,this breakage direction is called salty cleavage

2-Phyllite: is a foliated rock in which the micas have recrystallized to a greater extent than those in a slate it forms by recrystallization of slate. Foliation surface in phyllite have a more shiny appearance than those of a slate the clay-mica grains of slates have recrystallized to muscovite , biotitic or chlorite but remain fine grained .

3-Schist :in which mica and other minerals are completely recrystallized ,it is produced by regional metamorphism of phyllite ,and all major constituents of the rock should be visible to the unaided eye porphyrobiasts of garnet ,kynite ,staurotite and other minerals are common Instead of clays the micas muscovite and -Biotite and talc or chlorite may be the main constituent of this rock type.

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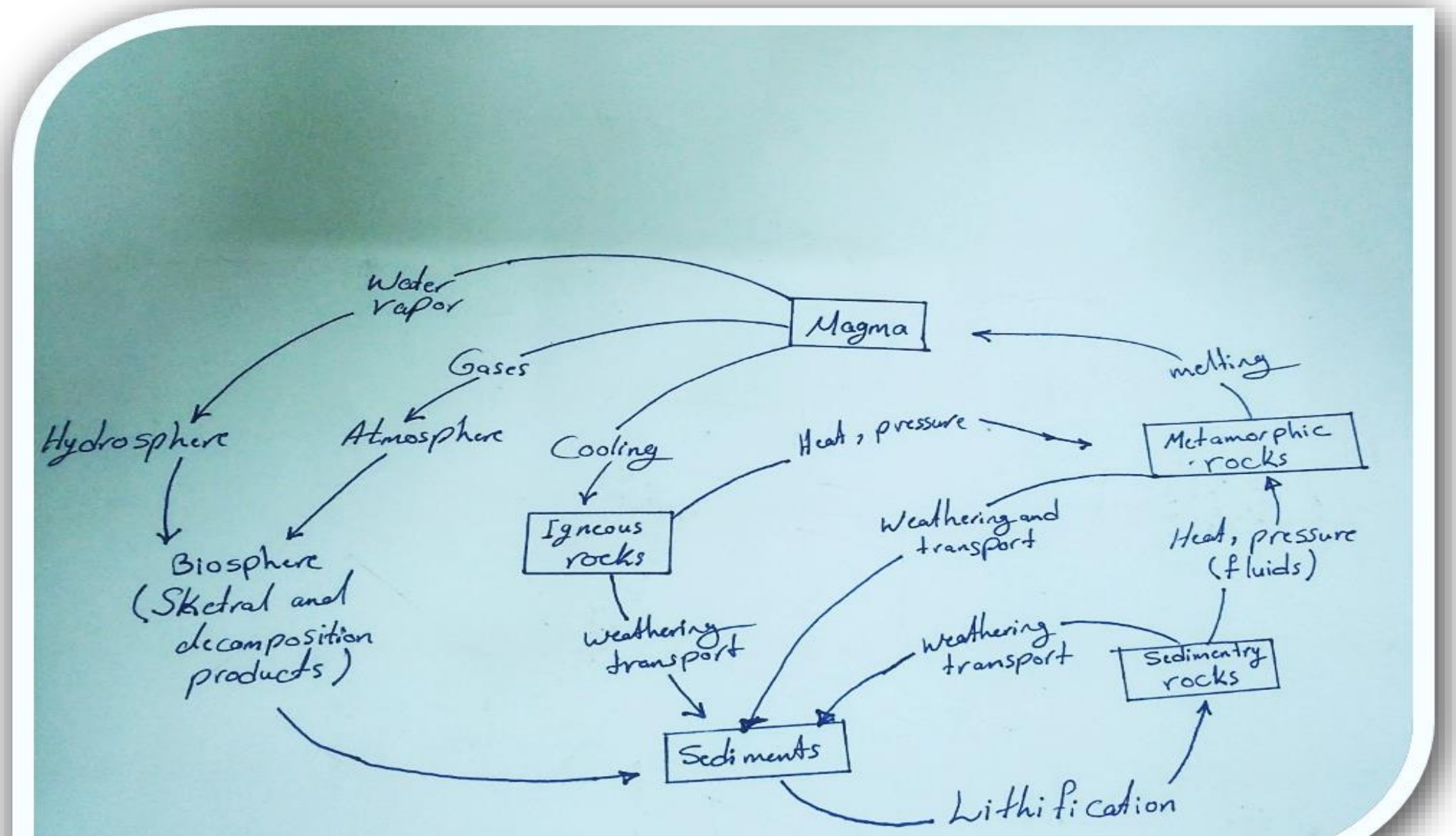

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