N.B.K.R. INSTITUTE OF SCIENCE & TECHNOLOGY:: VIDYANAGAR

(AUTONOMOUS)

CIVIL ENGINEERING

Academic Year: 2021-2022

Class-Semester: II.B.TECH , I SEM **Branch: Civil Engineering**

Course Code: 20CE2104 **Course Name: Engineering Geology**

Lecture on: Unit II -Petrology

Teacher: Dr.U.CHANDRA BHASKARA REDDY

Contents…….

- **Origin of rocks (Igneous, Sedimentary and metamorphic) and rock cycle.**
- **Structures and Textures of Igneous, Sedimentary and metamorphic.**
- **Classification of Igneous, Sedimentary and metamorphic rocks.**
- **Identifiation of Igneous, Sedimentary and metamorphic rocks.**

PETROLOGY

- **Petro = Rock**
- **Logy=Study**

  Thus petrology is a science, which explains about rock in terms of its

✓ Origin

✓ Mineral and Chemical composition

✓ Classification

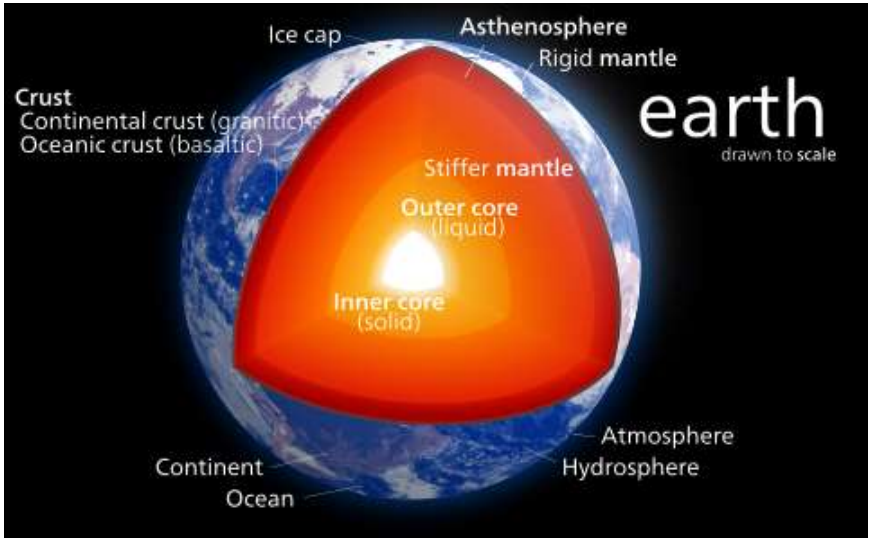
✓ Geographical distribution etc.

➢ **Rock**

Rock is constituents of various minerals.

✓Therefore any naturally occurring solid mass with aggregates of minerals is defined as rock.

✓Normally rocks formed in the crust and at upper mantle.



Biotite Mica Mineral

Plagioclase Feldspar Mineral

Pegmatite Rock

Igneous Rock

Origin of Rocks

Generally rocks are forming by various process such as

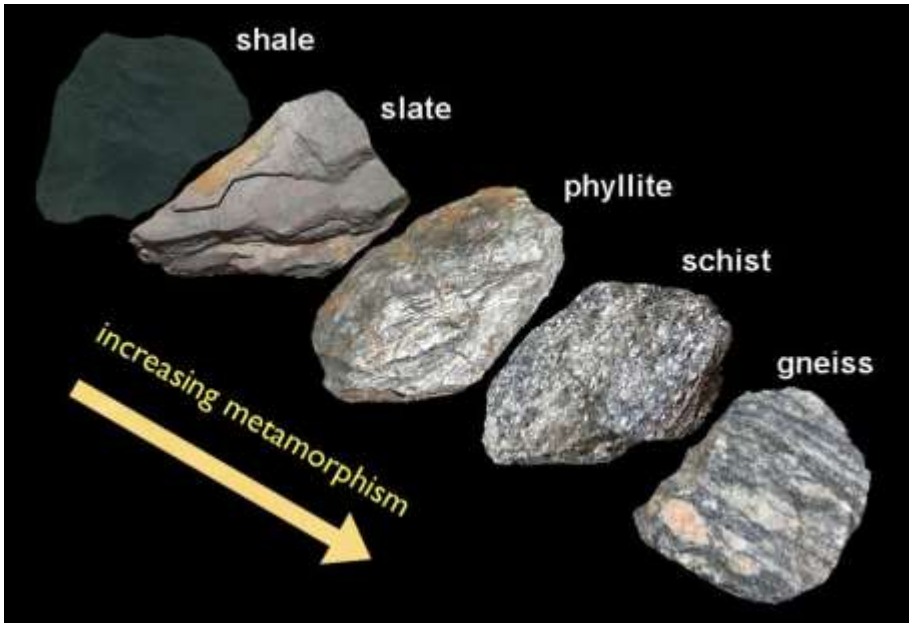
- Crystallization or Solidification of Magma (Plutonic and Hypabyssal) or Lava (Volcanic) - **(Igneous Rocks)**

- Weathering, erosion and deposition of various sediments and its digenesis- **(Sedimentary Rocks)**

- If existed rocks may change its physical and chemical characteristics due to temperature and elevated pressure, **Metamorphic Rocks** will be result**.**

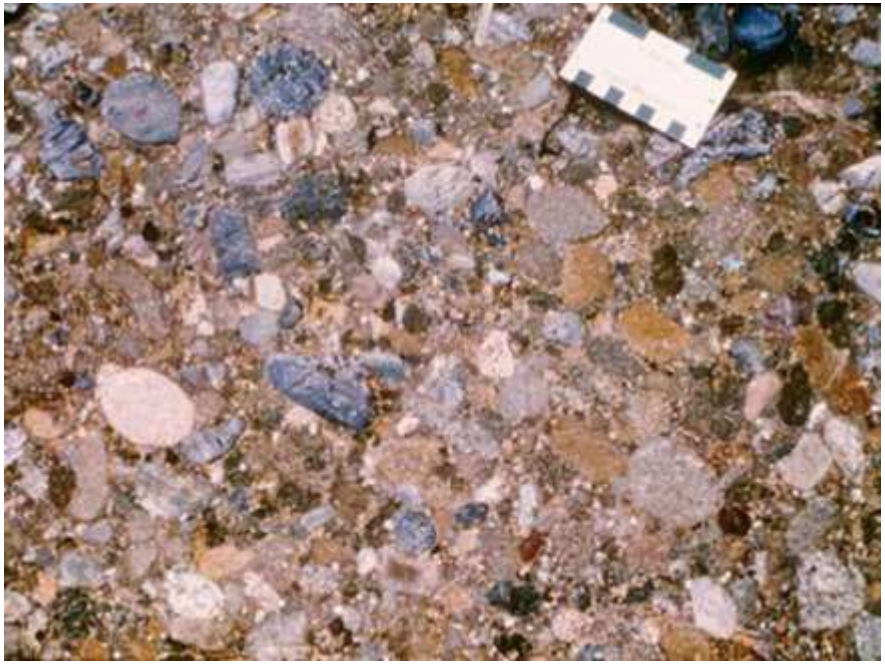
Igneous Rocks

Sedimentary Rocks



Metamorphic Rocks

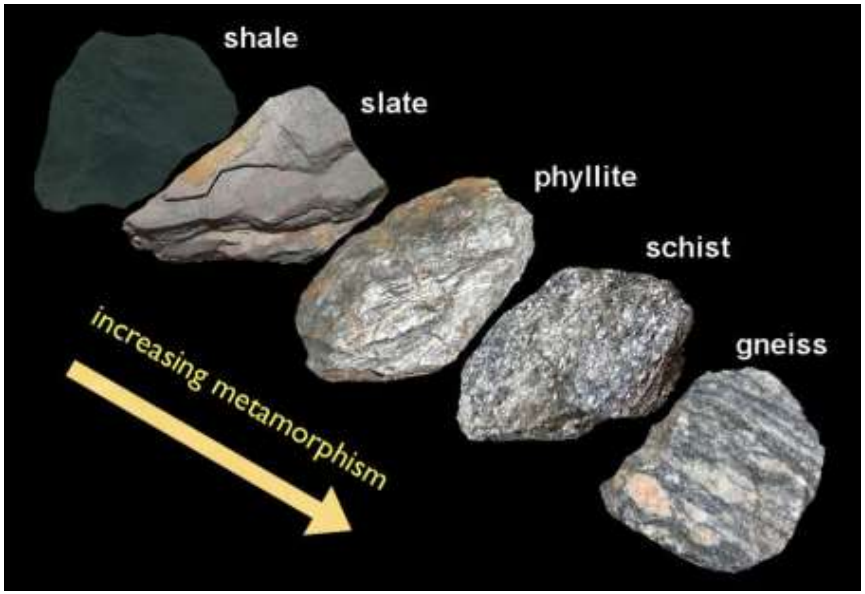
Sedimentary Rocks



Metamorphic Rocks

Schist

Gneiss



Granite

Igneous Rocks

Origin of Igneous Rocks

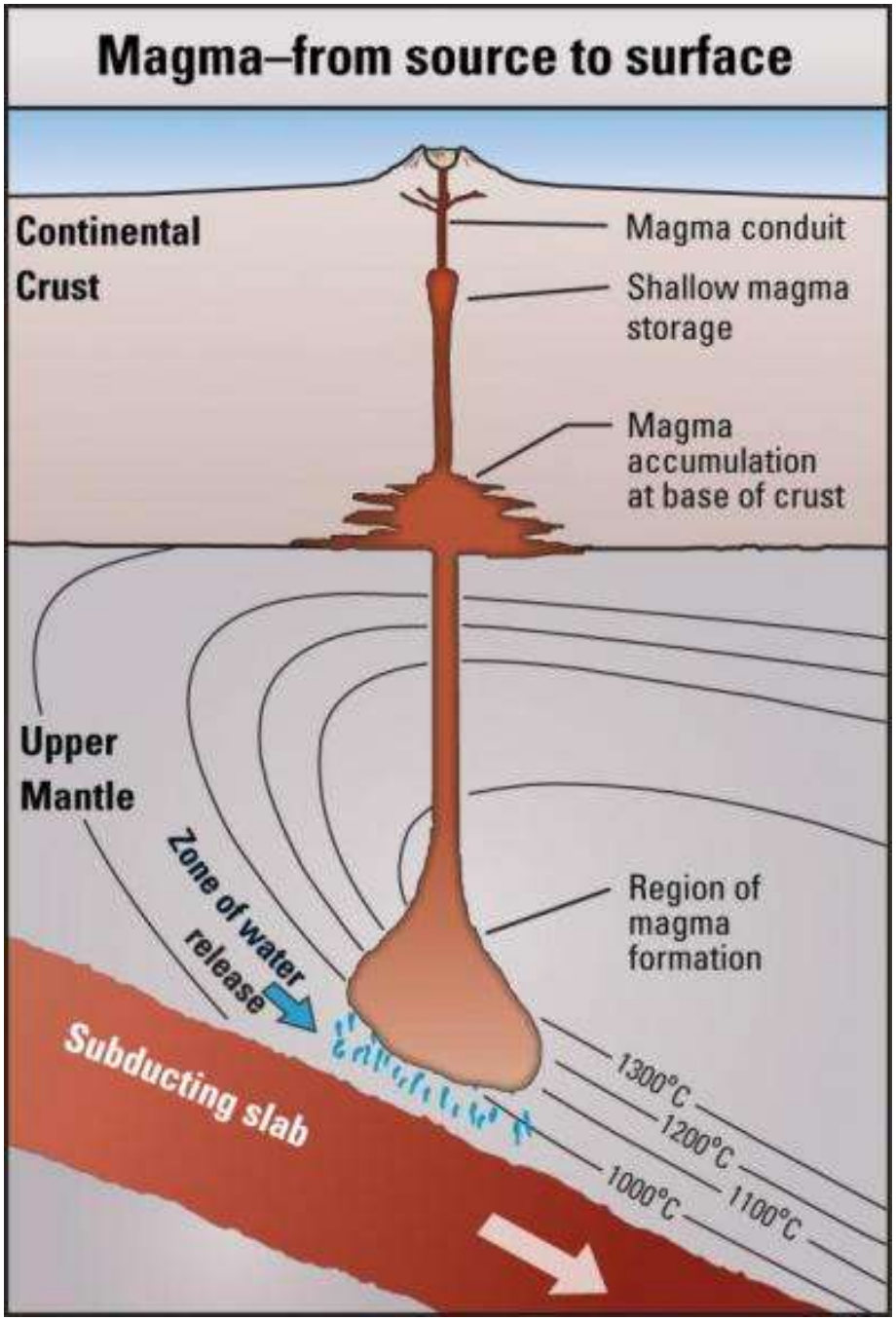
Igneous rocks are formed from magma or lava through crystallization or solidification.

✓Ignum means fire, therefore the rocks which are formed from the molten material is defined as igneous rocks.

✓Magma or lava crystallize at various portions of the earth crust, based on depth, where these rocks are formed is classified as

- ✓**Extrusive Igneous rocks**
  - •Volcanic Igneous rocks(Formed on or near the surface of the Earth)
- ✓**Intrusive Igneous rocks**
  - •Hypabyssal Igneous rocks(Formed at intermediate Depths)
  - •Plutonic Igneous rocks(Formed at greater depths)

Molten rock beneath the surface of the Earth.



Igneous Rocks are grouped into various on the basis of

1. Depth of formation and mineral grain size
2. Silica content & Mineralogical composition

➢**Based on depth of formation and Grain size ,** igneous rocks can be classified into three types as

1. **Volcanic rocks**: Lava cool quickly and solidified as finer-grained volcanic rocks, They may contain some larger crystals(phenocrysts), that formed earlier.
2. **Hypabyssal or sub volcanic rocks**: Form at intermediate depths (generally as dykes and sills) and so they consist medium-grained minerals
3. **Plutonic rocks**: Form deeper within the Earth and the slow cooling allows them to crystallize as coarse-grained rocks.

➢**Based on Silica content**

Silica (SiO_2) content also is used to classify igneous rocks as follows

Ultrabasic: Rocks that are usually >45% silica and rich in mafic minerals mainly such as olivine and pyroxene etc.

e.g. Peridotite.

Basic: Rocks that are about 45 to 55% silica, with mafic minerals, plagioclase feldspar etc.

e.g. Basalt.

Basalt.

Intermediate or Andesitic: Rocks about 55 to 65% silica and felsic minerals mainly **plagioclase** and mafic minerals mainly **hornblende**, pyroxene, and/or biotite).

e.g Diorite

Diorite

Acid: Rocks with above 65% silica with mostly feldspar minerals and quartz.

e.g. Granite.

Granite

Structures or Forms of Igneous Rocks

Structure: Structure included large scale features of rocks as

A.Extrusive structures, which are formed from lava explosion, flow and deposition.

- Lava flows
  - Ropy lava (a)
  - Block lava (b)
  - Pillow structures (c)

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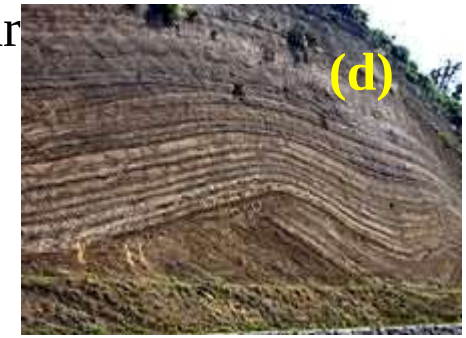
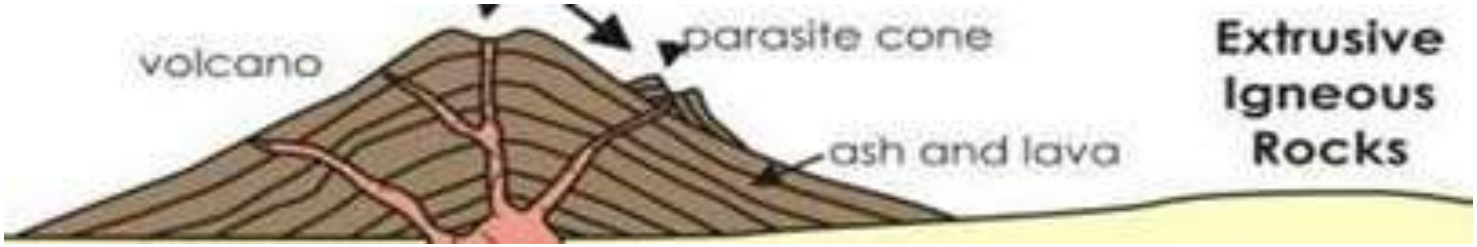
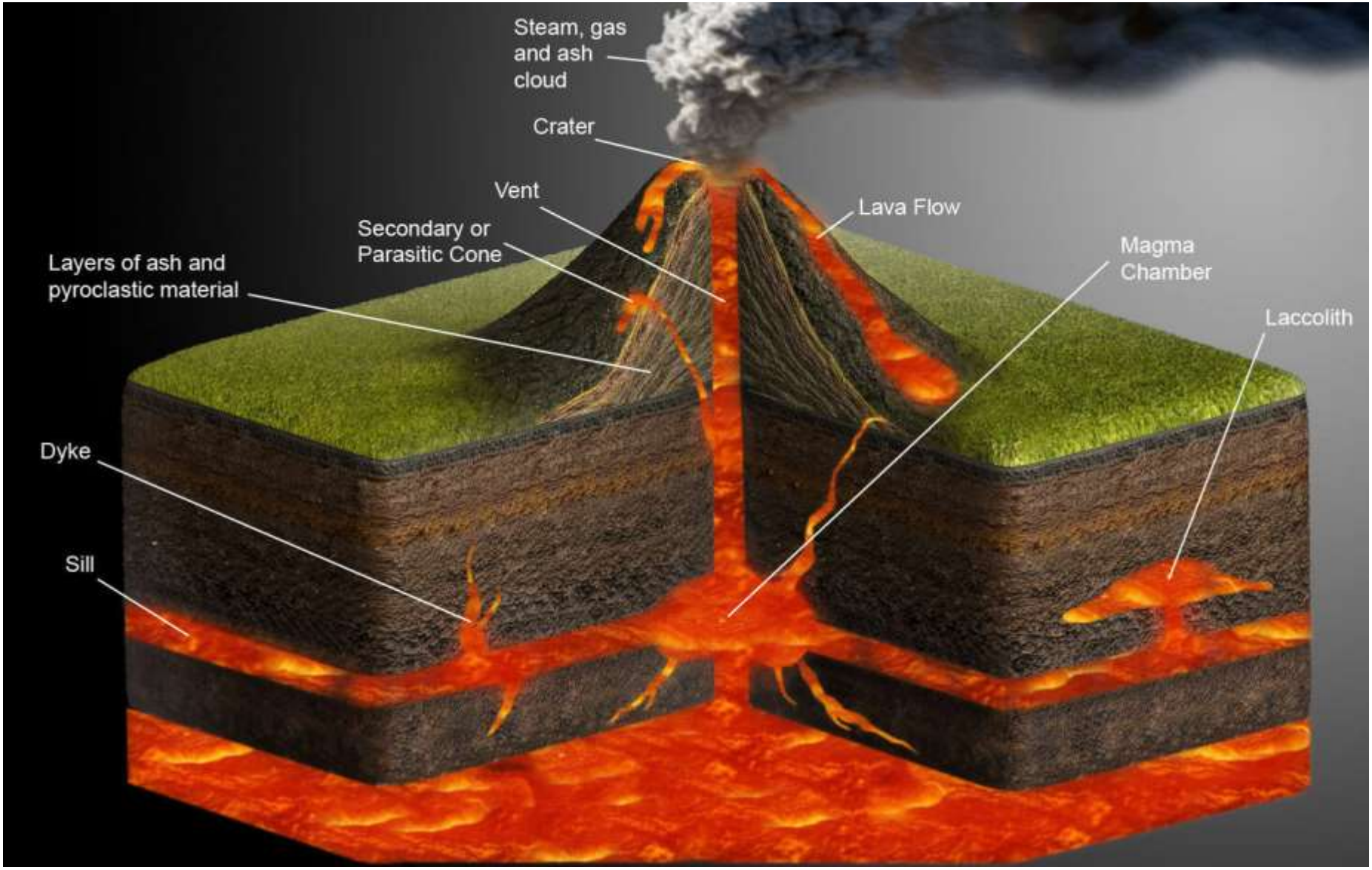
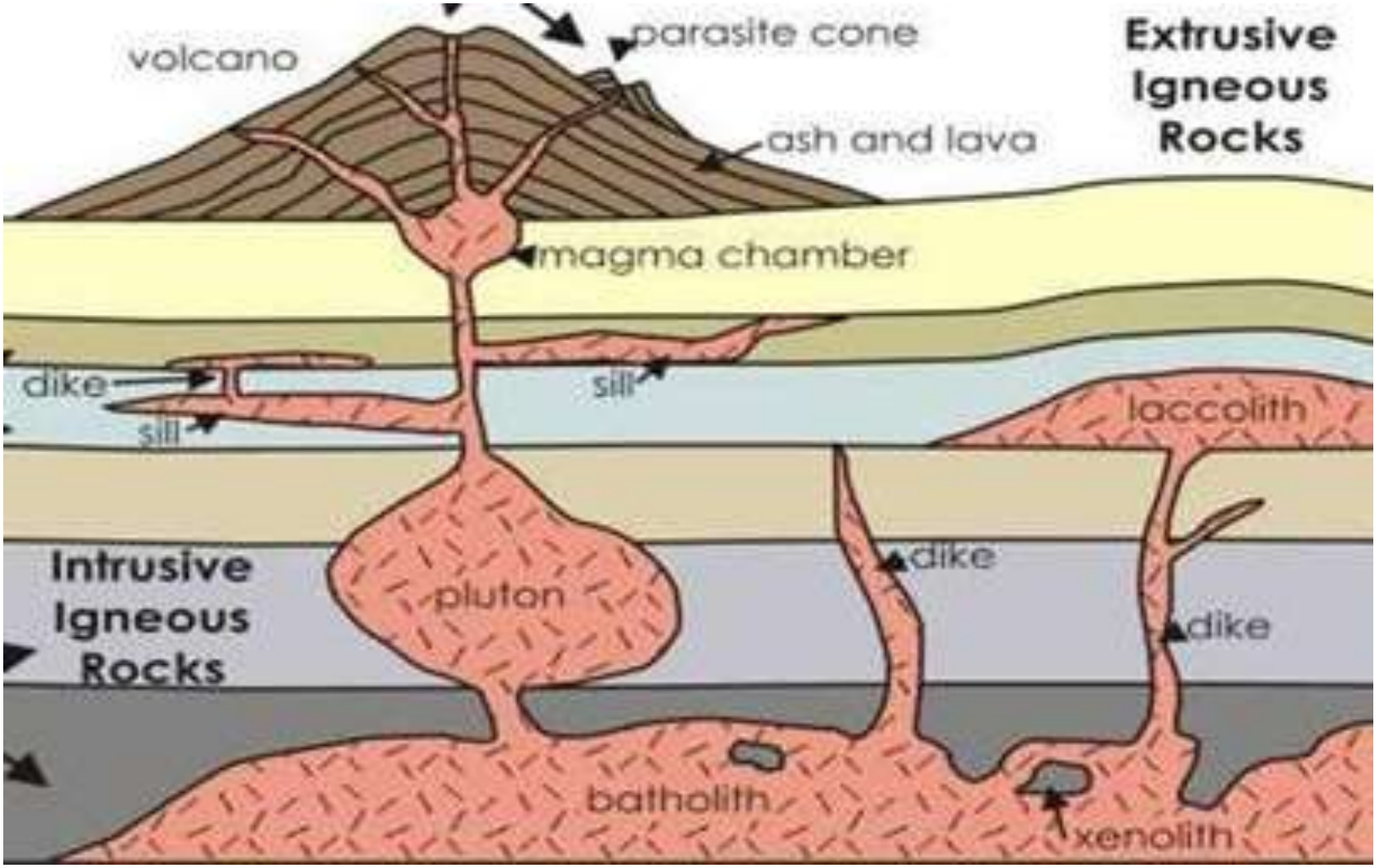





Steam, gas and ash cloud
Crater
Vent
Lava Flow
Secondary or Parasitic Cone
Magma Chamber
Layers of ash and pyroclastic material
Laccolith
Dyke
Sill


volcano
parasite cone
ash and lava
Extrusive Igneous Rocks
magma chamber
dike
sill
sill
laccolith
Intrusive Igneous Rocks
pluton
dike
dike
batholith
xenolith

Structures or Forms of Igneous Rocks

Structure: Structure included large scale features of rocks as

A.Extrusive structures, which are formed from lava explosion ,flow, and deposition.

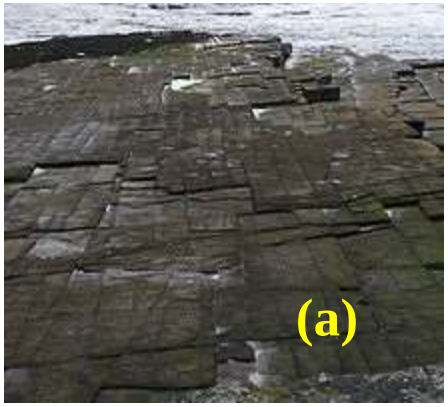
- **Pyroclastic deposits**
  - Volcanic bombs/ Volcanic blocks(Agglomerate)-(Particles size > 64mm)
  - Lapilli/Tephra (Particles size 2 to 64 mm)-(size of wall nut and pea)
  - Volcanic dust or sand, volcanic tuff etc.(particles <2mm in diameter)

Structures or Forms of Igneous Rocks

Structure: Structure included large scale features of rocks as

A.Extrusive structures, which are formed from lava explosion ,flow and deposition.

- **Parting structures**
  - Mural joints (a)
  - Sheet structures (b)
  - Columnar joints or Prismatic structures etc. (c)



(b)

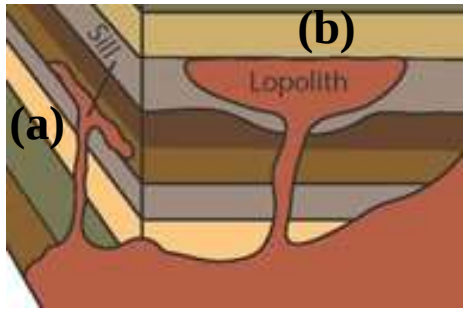
(c)

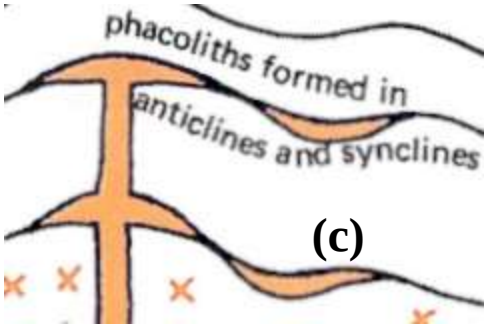
Structures or Forms of Igneous Rocks

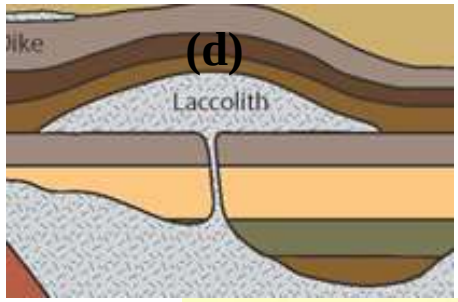
Intrusive structures: Molten rock mass forms various structures by injected or intruded between the layers of the Earth's crust is known as intrusive igneous structures as

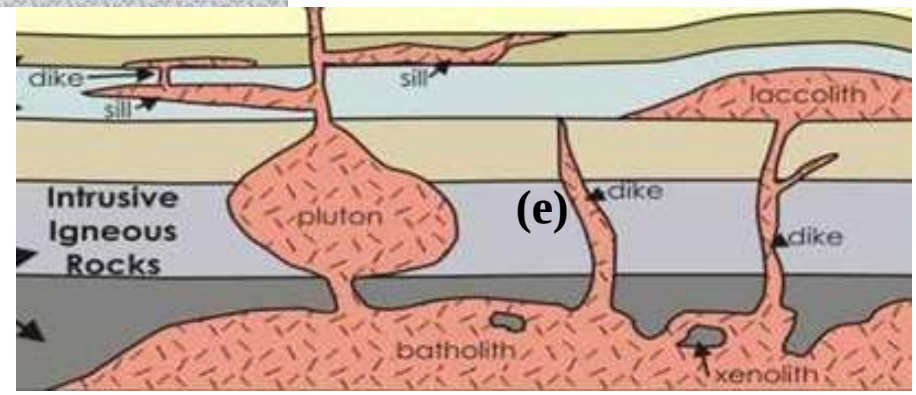
- **Concordant structures**
  - Sill (a),
  - Lopolith (b),
  - Phacolith (c),
  - Laccoliths (d).
- **Discordant structures**
  - Dyke (e)
  - Cone sheets
  - Volcanic neck
  - Ring dyke
  - Stock, bosses,
  - Discordant batholiths

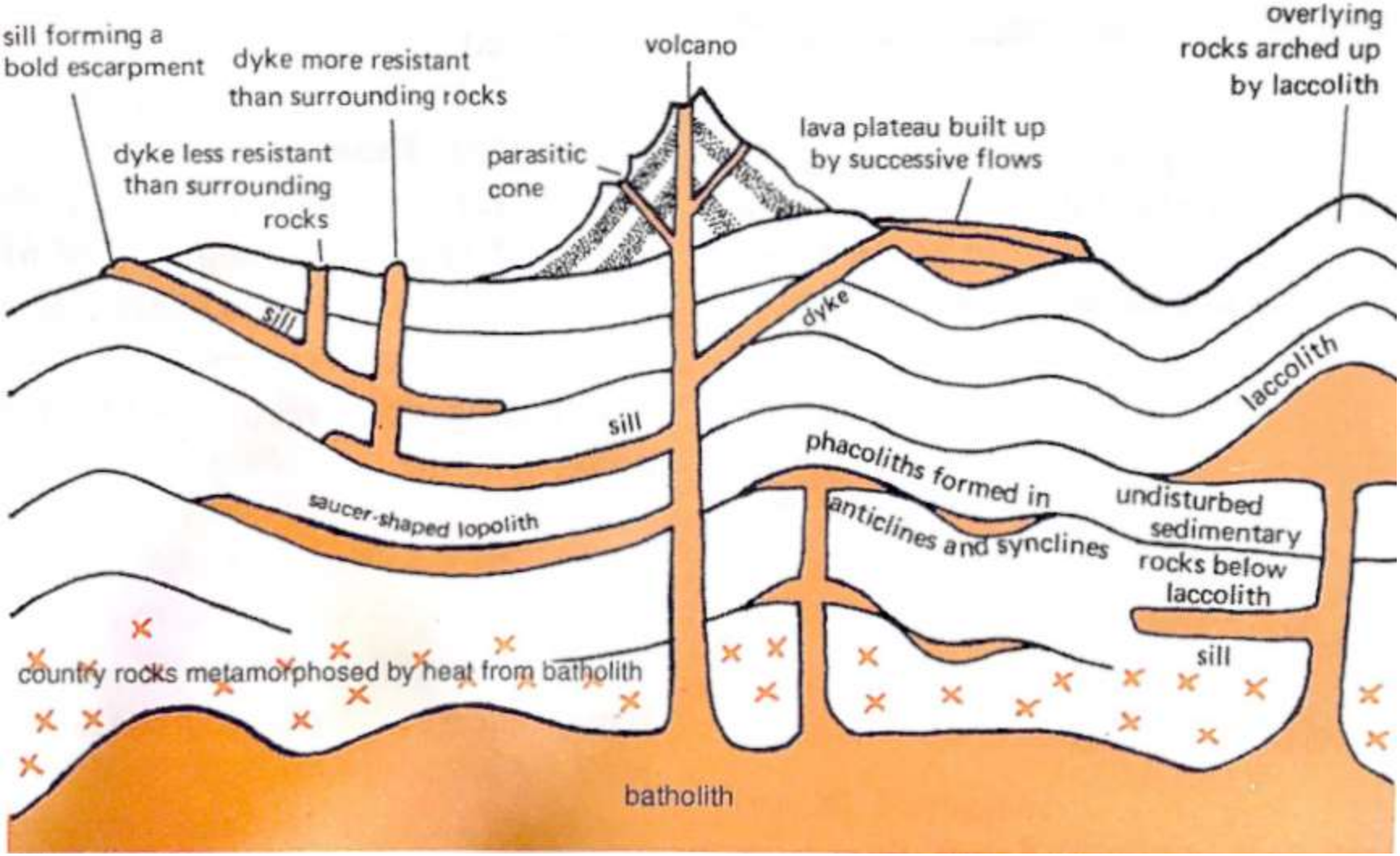
  (>100 square KM areal extent)

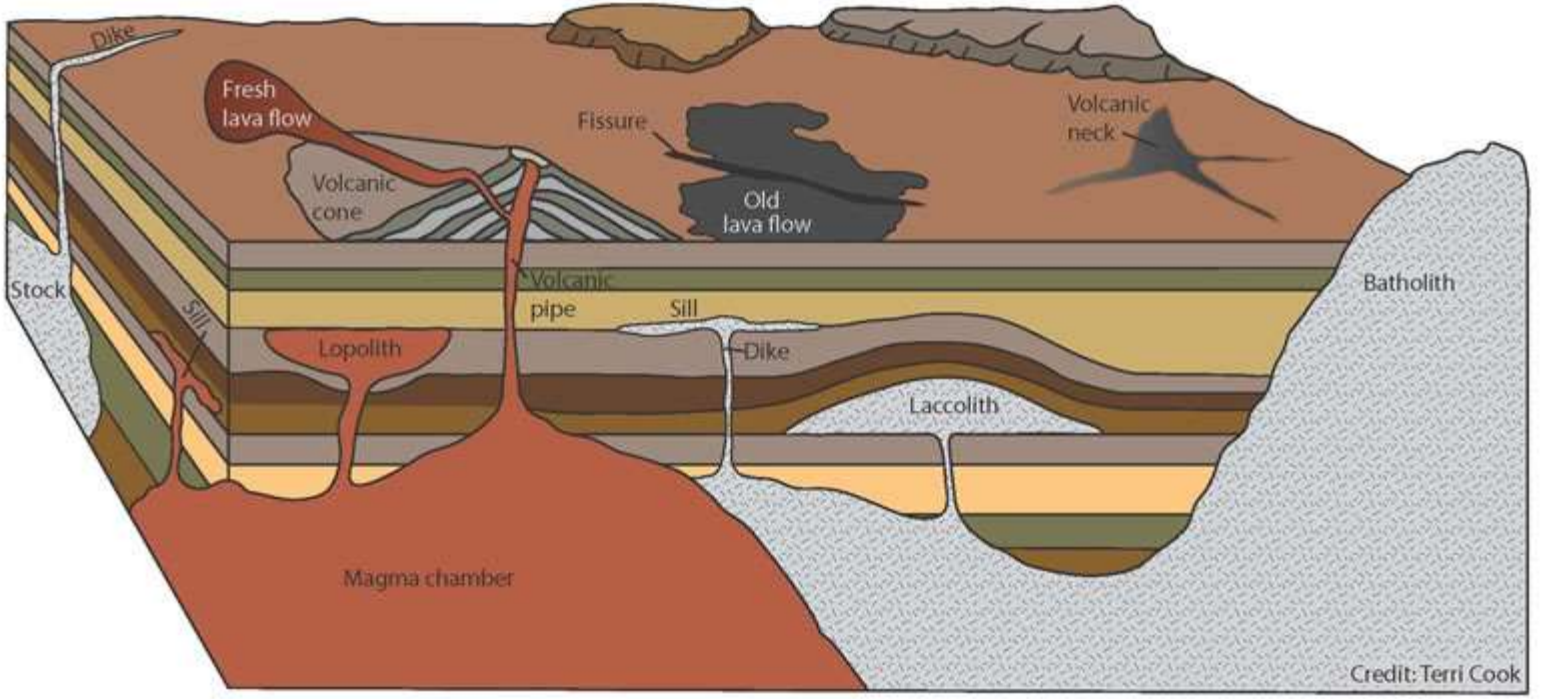









sill forming a bold escarpment
dyke more resistant than surrounding rocks
volcano
overlying rocks arched up by laccolith
dyke less resistant than surrounding rocks
parasitic cone
lava plateau built up by successive flows
sill
dyke
laccolith
sill
phacoliths formed in anticlines and synclines
undisturbed sedimentary rocks below laccolith
saucer-shaped lopolith
sill
country rocks metamorphosed by heat from batholith
batholith


Dike
Fresh lava flow
Fissure
Volcanic neck
Volcanic cone
Old lava flow
Stock
Sill
Volcanic pipe
Sill
Batholith
Lopolith
Dike
Laccolith
Magma chamber
Credit: Terri Cook

Textures of Igneous Rocks

Texture: The mutual relationship of the mineral constituents and glassy material in a rock is known as texture of rock. Normally it is best studied in thin section under microscope. Description of texture requires consideration of four points.

- **Degree of crystallization or crystallinity**
  - Holocrystalline (a)
  - Mero or hypo and hemicystalline (b)
  - Holohyaline (c)
- **Size of mineral grains or granularity**
  - Phanerocystalline or Phaneric
    - ✓ Coarse grain(>5mm) (d)
    - ✓ Medium grained(5mm to 1mm) (e)
    - ✓ Fine grained(<1mm) (f)
  - Aphanetic
    - ✓ Mirocrystalline,
    - ✓ Cryptocrystalline

(a)

(b)

(c)

(d)

(f)

(e)

Textures of Igneous Rocks

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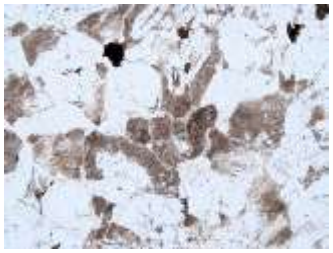
- **Shape of crystals**
  - Euhedral (b)
  - Subhedral (b)
  - Anhedral (c)

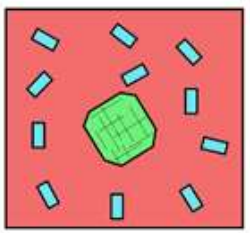
(a)

(b)

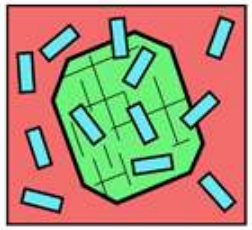


(c)

- **Mutual relationship of crystals**
  - Equigranular
    - ✓ Allotriomorphic (most anhedral)
    - ✓ Hypidiomorphic (most subhedral)
    - ✓ Panidiomorphic (most euhedral)
  - Inequigranular
    - ✓ Porphyritic (d)
    - ✓ Poikilitic (e)
  - Directive textures
    - ✓ Fluidal
    - ✓ Trachytic
    - ✓ Intergranular



(d)



(e)

		Over Saturated			Saturated			Under saturated		
		I Quartz	II Quartz+ Feldspar		III Feldspar			IV Feldspar+ Feldspathoids	V Feldspathoids	VI Mafic minerals predominant
			Predominant of orthoclase	Predominant of plagioclase	Predominant of alkali feldspar (or, Ab)	Predominant of Soda-limeplagioclase feldspar	Predominant of lime-Sodaplagioclase feldspar			
PLUTONIC	F	IQV	Granite	Granodiorite	Syenite	Diorite	Anorthosite	Nepheline Syenite	- Ijolite	- - Peridotite /Picrite
	MF		-	-	-	-	Gabbro	Theralite		
	M		-	-	-	-	-	Tesch -	-	
HYPABYSSAL	F		←	←	Applites →			→	→	→
	MF		← Granophyre, Felsite	←	Porphyries →					
	M		←	Pitchstone	Lamprophyres →	→	Dolerite			
							Tachylit			
VOLCANIC	F		Rhyolite	Dacite	Trachyte	Andesite	Basalt	Phonolite	Leucitophyre	Oliine-rich Basalt
	MF		←	Pitchstone Obsidian →	→		Tachylite		Nephelin e-Basalt	
	M								Leuite-Basalt	Linburgit e
Avg Na %		90	72	66	59	57	48	54.5	43	41

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- **Shape of crystals**
  - Euhedral
  - Subhedral
  - Anhedral
- **Mutual relationship of crystals**
  - Equigranular
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  - Inequigranular
    - ✓ Porphyritic
    - ✓ Poikilitic
  - Directive textures
    - ✓ Fluidal
    - ✓ Trachytic
    - ✓ Intergranular

Sedimentary Rocks

Sediment: An unconsolidated material due to weathering, transportation and deposition of existed rocks by wind, water, ice and force of gravity. It varies in size from very big boulders to fine clay.

Clastic sediments: Fragments of rocks and minerals.

Chemical sediments: Material dissolved in water, and chemically precipitates from the water.

Biochemical sediments: Living organisms extract ions dissolved in water to make such things as shells and bones.

organic sediments: Accumulation of plant matter at the bottom of a swamp.

Sedimentary rock: A type of rocks formed by the accumulation or deposition, compaction and cementation of sediments (minerals or other organic particles)on the earth's surface is defined as sedimentary rock.

- **Classification of sedimentary rocks:**
  - ✓ **Clastic Sedimentary Rocks**,
  - ✓ **Chemical Sedimentary Rocks**,
  - ✓ **Biochemical Sedimentary Rocks**, and
  - ✓ **Organic Sedimentary Rocks**.

Processes involved in formation of Sediments and Sedimentary Rocks

The formation of a clastic sediment and sedimentary rocks involves five processes

1. **Weathering:**The first step is transforming solid rock into smaller fragments or dissolved ions by physical and chemical weathering.
2. **Erosion:** Processes lower the surface of the earth is erosion. it begins the transportation of weathered products from their original location by
   - ✓ gravity (massmovement events like landslides or rock falls),
   - ✓ by running water.
   - ✓ by wind, or by moving ice.

   Erosion overlaps with transportation.
3. **Transportation**: Sediment can be transported by sliding down slopes,
   - ✓ Picked up by the wind
   - ✓ carried by running water in streams, rivers, or ocean currents.
   - ✓ By glaciers or moving ice
4. **Deposition:** If the velocity of the transporting medium becomes too low to transport sediment, the sediment will fall out and become deposited as layers.
5. **Lithification or Diagenesis:** Lithification is the process that turns sediment into rock.
   - ✓ The first stage of the process is compaction.
   - ✓ The next stage is Cementation

Classification of clastic sedimentary rocks.

➢***Conglomerates and Breccias:*** Rocks that contain an abundance of coarse grained clasts (pebbles, cobbles, or boulders).

Conglomerate: Rock contains well rounded **c**oarse grained clasts. well rounded, indicating that they spent considerable time in the transportation process and were ultimately deposited in a high energy environment capable of carrying the large clasts.

Breccia:,The rock composed of coarse grained very angular angular clasts. Angularity, indicating that the clasts spent little time in the transportation cycle.

➢***Sandstones:***A Sandstone is made of sand-sized particles and Quartz is the dominant mineral in sandstones. On the basis of quartz parentage sandstones are different as

- ✓A Quartz arenite – is nearly 100% quartz grains.
- ✓ An Arkose contains abundant feldspar.
- ✓ In a lithic sandstone, the grains are mostly small rock fragments.
- ✓ A Wacke is a sandstone that contains more than 15% mud (silt and clay sized grains)..

Sandstones are one of the most common types of sedimentary rocks.

➢***Mudrocks:***Mudrocks are made of fine grained clasts (silt and clay sized) .

- ✓ A siltstone is one variety that consists of silt-sized fragments.
- ✓ A shale is composed of clay sized particles and tends to break into thin flat fragments.
- ✓ A mudstone is similar to a shale, but does not break into thin flat fragments.
- ✓ Organic-rich shale's are the source of petroleum.

Fine grained clastics are deposited in calm water, where there is little energy to continue to transport the small grains. Thus mud rocks form in deep water ocean basins and lakes.

Chemical Sediments and Sedimentary Rocks

When water evaporates, minerals dissolved in water can accumulate by chemical precipitation to become chemical sediments and chemical sedimentary rocks.

These are:

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

Travertine - Groundwater containing dissolve calcium and bicarbonate can precipitate to form limestone (chemically precipitated), called travertine. This can occur in lakes, hot springs, and caves.

Dolostones - If limestone chemically modified ($CaCO_3$ is altered as dolomite $CaMg(CO_3)_2$) by Mg-rich fluids flowing through the rock are converted to dolostones.

Chemical Cherts - Groundwater flowing through rock can precipitate SiO_2 to replace minerals that were present. This produces many varsities of chert with different names as

- ✓Flint – Black or gray from organic matter.
- ✓Jasper – Red or yellow from Fe oxides.
- ✓Petrified wood – Wood grain preserved by silica.
- ✓Agate – Concentrically layered rings

Evaporites

Rock salt

Rock salt

Travertine

Travertine limestone

Dolomite

Chemical Chert

Flint – Black or gray

Jasper

Biochemical and Organic sediments and sedimentary rocks

When the organism dies, the remains can accumulate to become sediment or sedimentary rock is known as biochemical and organic sedimentary rocks. They are

Biochemical Limestone **-** Calcite ($CaCO_3$) is precipitated by organisms usually to form a shell or other skeletal structure. Accumulation of these skeletal remains results in formation of limestone.

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

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

Coal **-** Coal is an organic rock made from remains of fossil plant matter.

It accumulates in lush tropical wetland settings and requires deposition in absence of Oxygen. It is high in carbon and can easily be burned to obtain energy.

Limestone

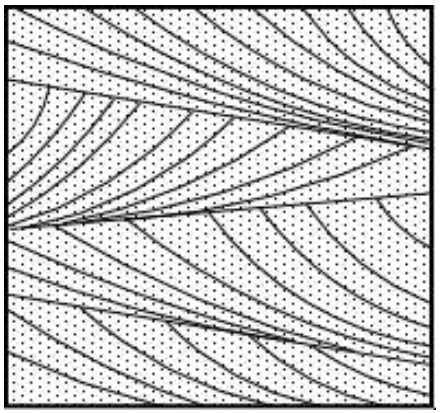
Biochemical Chert

Diatomite

Coal

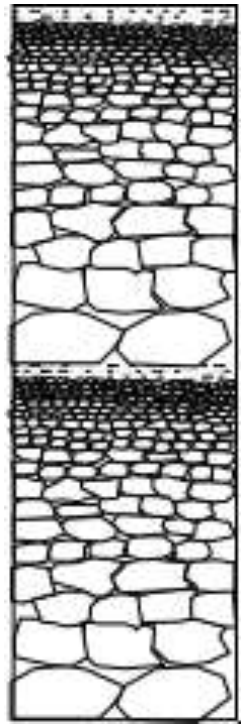
Sedimentary Structures

When the sediments is deposited under favorable conditions and from various direction, thus sedimentary rocks produce numerous structures.



Stratification and Bedding

Because sediment is deposited in wide areas, successive depositional events produce layers called bedding or stratification.

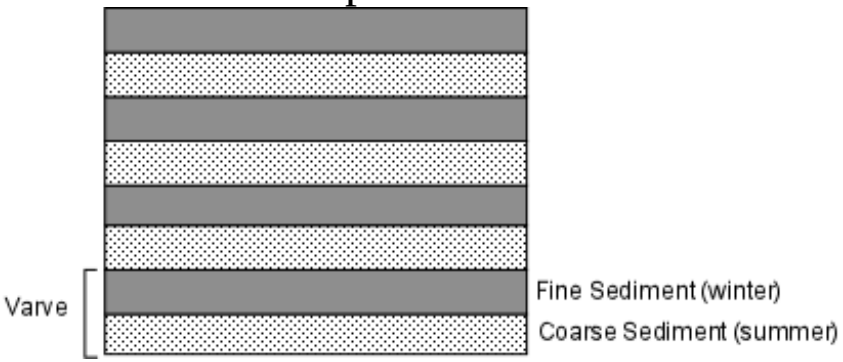


A series of beds are referred to as strata.
A sequence of strata that is sufficiently unique to be recognized on a regional scale is termed a formation.
A formation is the fundamental geologic mapping unit.

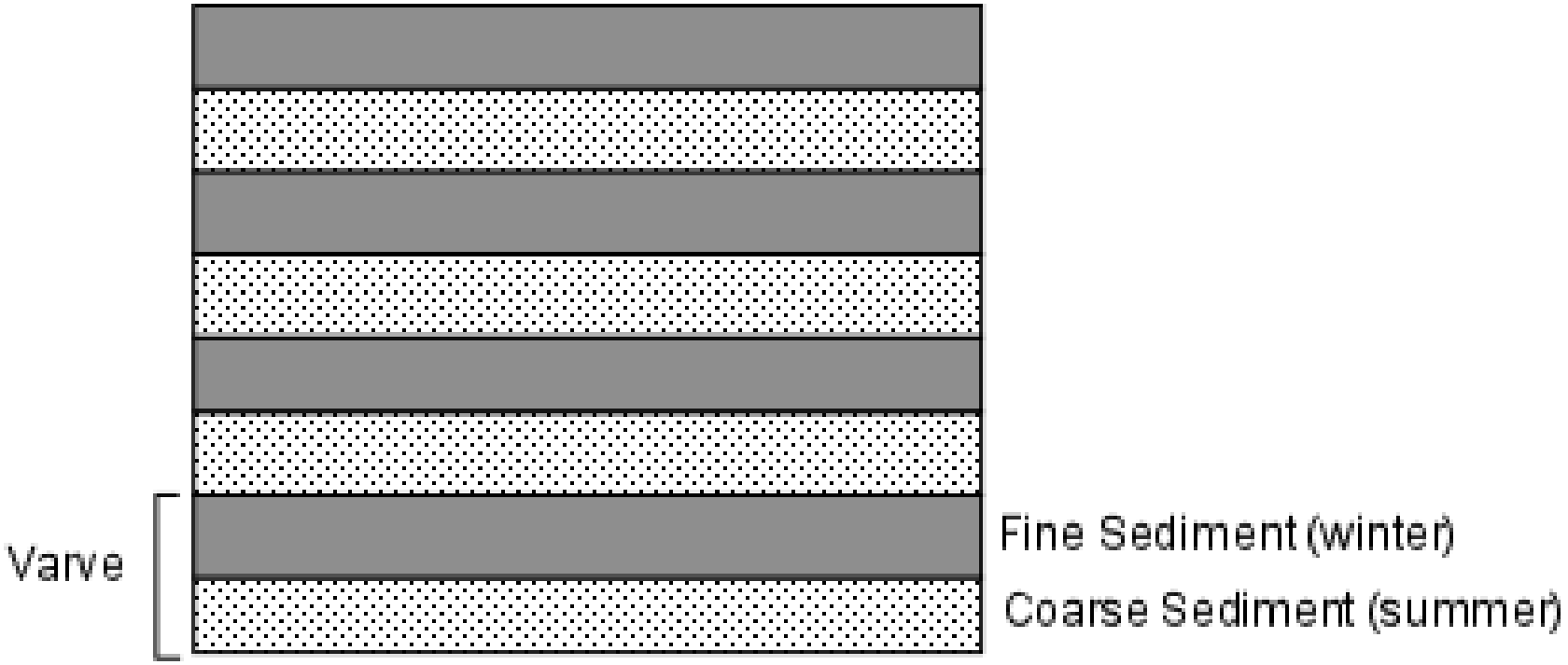
The layering can be due to differences in grain size of sediment, or differences in mineral content or chemical composition.

Various types of Bedding are

- ✓**Rhythmic Layering**
- ✓**Cross Bedding**
- ✓**Graded Bedding**



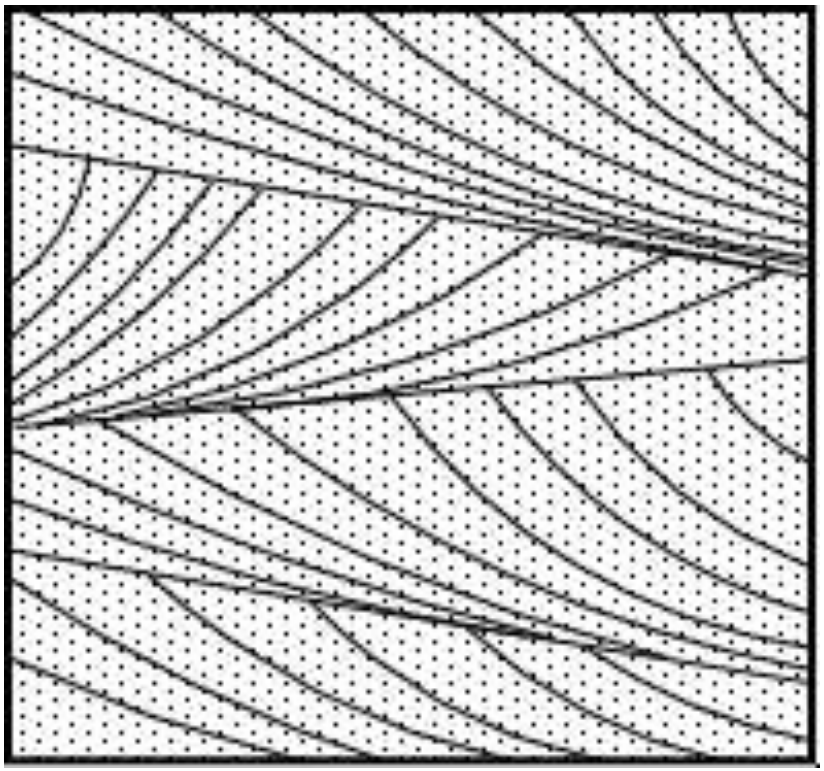
Rhythmic Layering - Seasonal changes in deposition causes coarse sediment is deposited first, then fine sediment.



➢**Cross Bedding*:*** Sets of beds that are inclined relative to one another.

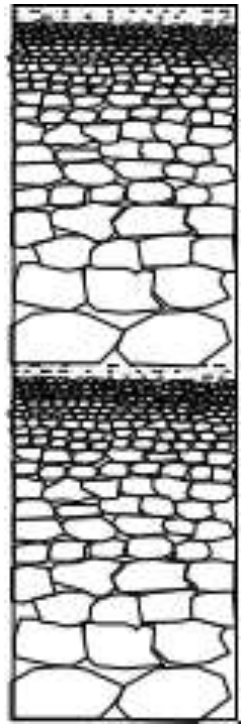
The beds are inclined in the direction that the wind or water was moving at the time of deposition.

Boundaries between sets of cross beds usually represent an erosional surface. Very common in beach deposits, sand dunes, and river deposited sediment.



Graded Bedding - As current velocity decreases, bedding showing a decrease in grain size from the bottom of the bed to the top of the bed.

Multiple graded-bed sequences called turbidites .



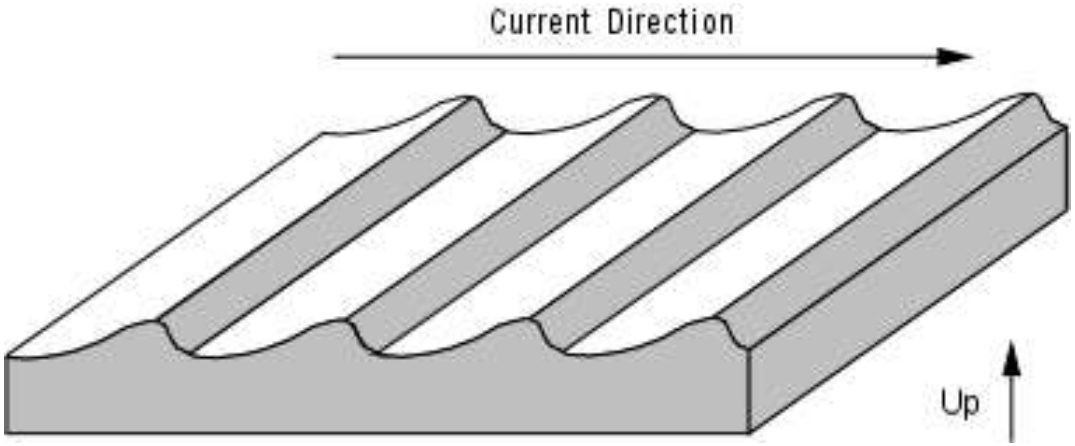
Non-sorted Sediment - Sediment showing a mixture of grain sizes results from rockfalls, debris flows, mudflows, and deposition from melting ice.

Ripple Marks - Water flowing over loose sediment creates bedforms by moving sediment with the flow.

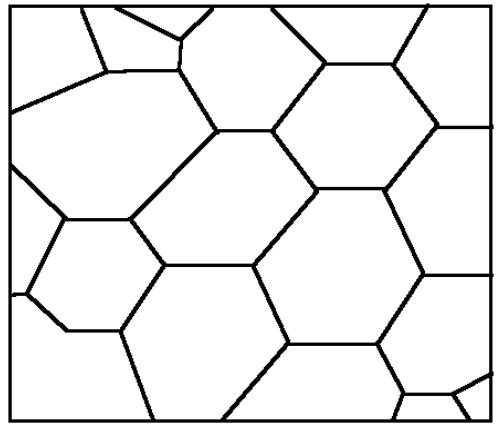
Bedforms are linked to flow velocity and sediment size. Ripples are characteristic of shallow water deposition and can also be caused by wind.

Asymmetric ripples indicate the steep slope on the down - current direction.

Symmetric ripples form as a result of constant wave energy oscillating back and forth.



Mudcracks When drying out of wet sediment at the surface of the Earth. It forms cracks due to shrinkage of the sediment as it dries.



•**Sole Marks** - Flutes are troughs eroded in soft sediment that can become filled with mud. Both the flutes and the resulting casts (called flute casts) can be preserved in rock.

•**Raindrop Marks** - pits (or tiny craters) created by falling rain. If present, this suggests that the sediment was exposed to the surface of the Earth just prior to burial.

•***Fossils*** **-** Remains of once living organisms. Probably the most important indicator of the environment of deposition.

- Different species usually inhabit specific environments.
- Because life has evolved - fossils give clues to relative age of the sediment.
- Can also be important indicators of past climates.

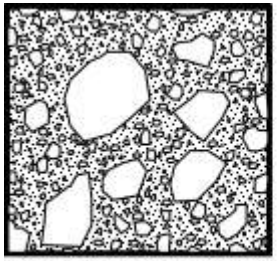
•***Rock Color***

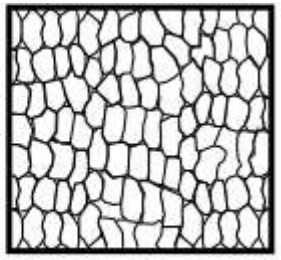
- Sulfides along with buried organic matter give rocks a dark color. Indicates deposition in a reducing environment.
- Deposition in oxidizing environment produces red colored iron oxides and is often indicative of deposition in a non-marine environment.
- Such red colored rocks are often referred to as red beds

Sedimentary Environments can be divided into the following

- **Terrestrial (Non-marine) environments**
  - Glacial
  - Alluvial fans
  - Sand Dunes
  - Mountain Streams
  - Lakes
  - Rivers
- **Marine environments**
  - Deltas
  - Coastal Beaches
  - Shallow Marine Clastics
  - Shallow Marine Carbonates
  - Deep Marine

Sedimentary Textures

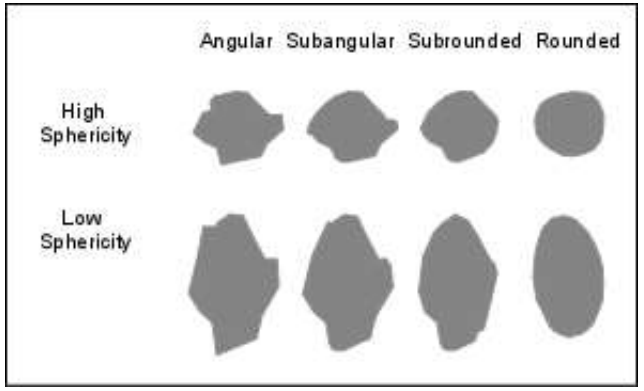

Poorly Sorted Sediment


Well Sorted Sediment

Textures of Clastic Sedimentary Rocks

1.Sorting: The degree of uniformity of grain size.

- **Poorly sorted**--Stream deposits are usually poorly sorted.
- **Well sorted** --Beach deposits and wind blown deposits are well sorted.



2.Rounding - During the transportation process, grains may be reduced in size due to abrasion.

Rounding is classified on relative terms as

- ✓ Rounded
- ✓ Sub rounded
- ✓ Sub angular
- ✓ Angular

Sediment Maturity: Sediment that is well rounded and well sorted.

The Wentworth scale of sediments

Millimeters	Wentworth Grade	Phi (Φ) Scale
>256	Boulder	–8
>64	Cobble	–6
>4	Pebble	–2
>2	Granule	–1
>1	Very coarse sand	0
>1/2	Coarse sand	1
>1/4(0.25)	Medium sand	2
>1/8(0.125)	Fine sand	3
>1/16(0.0625	Very fine sand	4
>1/32(0.03125)	Coarse silt	5
>1/64(0.015625)	Medium silt	6
>1/128(0.0078125)	Fine silt	7
>1/256(0.00390625)	Very fine silt	8
<1/256(0.001953125)	Clay	>8

Grain size and the rock name.

Name of Particle	Size Range	Loose Sediment	Consolidated Rock
Boulder	>256 mm	Gravel	
Cobble	64 - 256 mm	Gravel	Conglomerate or Breccia (depends on rounding)
Pebble	2 - 64 mm	Gravel	
Sand	1/16 - 2mm	Sand	Sandstone
Silt	1/256 - 1/16 mm	Silt	Siltstone
Clay	<1/256 mm	Clay	Claystone, mudstone, and shale

Clastic Sedimentary rocks

Chemical Sedimentary rocks

Limestone

Chert

Bio-Chemical Sedimentary rocks

Shelly limestone

Organic Sedimentary rocks

Coal

Conglomerate

Texture: Clastic (coarse-grained).

Grain size: > 2mm; Clasts easily visible to the naked eye, should be identifiable.

Colour: variable, dependent on clast and matrix composition.

Composition:

Clast: Rounded clasts of conglomerate can be mineral particles such as quartz, or they can be sedimentary, metamorphic, or igneous rock fragments.

The matrix: Large clasts together can be bind by a mixture of sand, mud, and chemical cement.

Mode of Origin: Conglomerates are deposited in various sedimentary environments like deep water and shallow marine, fluvial,alluvial,glacial.

Uses: Conglomerate can be crushed to make a fine aggregate that can be used where a low-performance material is suitable. Many conglomerates are colorful and attractive rocks, but they are only rarely used as an ornamental stone for interior use.

Conglomerate

Breccia

Texture: Clastic (coarse-grained).

Grain size: > 2mm; Clasts easily visible to the naked eye, should be identifiable.

Colour: variable, dependent on clast and matrix composition.

Composition:

Clast: Variable Angular clasts generally harder rock types and / or minerals dominate.

The matrix:Angular Large clasts together can be bind by calcite, silica or iron oxide as matrix matrial.

Mode of Origin: consolidated material accumulated on steep hill slopes or at the foot of cliffs. fragmentation of rocks during faulting(Cataclastic breccia). Volcanic breccias (agglomerates) the product of an explosive eruption. Hydrothermal breccias are formed when hydrothermal fluid fractures a rock mass.

Impact breccias are formed when a meteor impacts the Earth's surface, fracturing rock at the site of the impact..

Uses: as dimension stone for decoration of walls and floors; if hard can be used as aggregate, fill etc. in the construction.

Breccia

Sandstone

Texture: Clastic (fine-grained) -noticeable with a microscope).

Grain size: 0.06 - 2mm; clasts visible to the naked eye.

Colour: Variable through grey, yellow, red to white reflecting the variation in mineral content and cement.

Composition:

Clast: Dominantly quartz and feldspar (orthoclase, plagioclase) with lithic clasts and varying minor amounts of other minerals..

The matrix: Quartz, calcite, and clays.

Mode of Origin: Sandstone is a sedimentary rock formed from cemented sand-sized clasts.

Uses: if hard then can be used as aggregate, fill etc. in the construction and dimension stone for buildings, paving, etc.

Sandstone

Sandstone

Mudstone & Shale

Texture: Clastic (fine-grained) -noticeable with a microscope).

Grain size: Very fine-grained (< 0.06mm); clasts not visible to the naked eye.

Colour: variable - black, white, grey, brown, red, green, blue etc

Composition:

Clast: Generally a mixture of clay minerals with any or all of quartz, feldspar (orthoclase, plagioclase), mica (biotite, chlorite, muscovite); can contain iron oxides (cause red or yellowish colouring); black colouring due to carbonaceous content and / or pyrite..

The matrix: vary from clay minerals to calcite, silica or iron oxides

Mode of Origin: Mudstone is an extremely fine-grained sedimentary rock consisting of a mixture of clay and silt-sized particles

Uses: if hard then can be used as aggregate, fill etc. in the construction and dimension stone for buildings, paving, etc.

Mudstone

Shale

Limestone

Texture: Clastic or non-clastic

Grain size: consist of various clasts of all sizes.

Colour: Variable, but generally light coloured, grey through yellow.

Composition:

Clast: if clastic grains of calite mineral, if bioclastic then broken or whole shell fragments as calcite visible.

The matrix: Siliceous material.

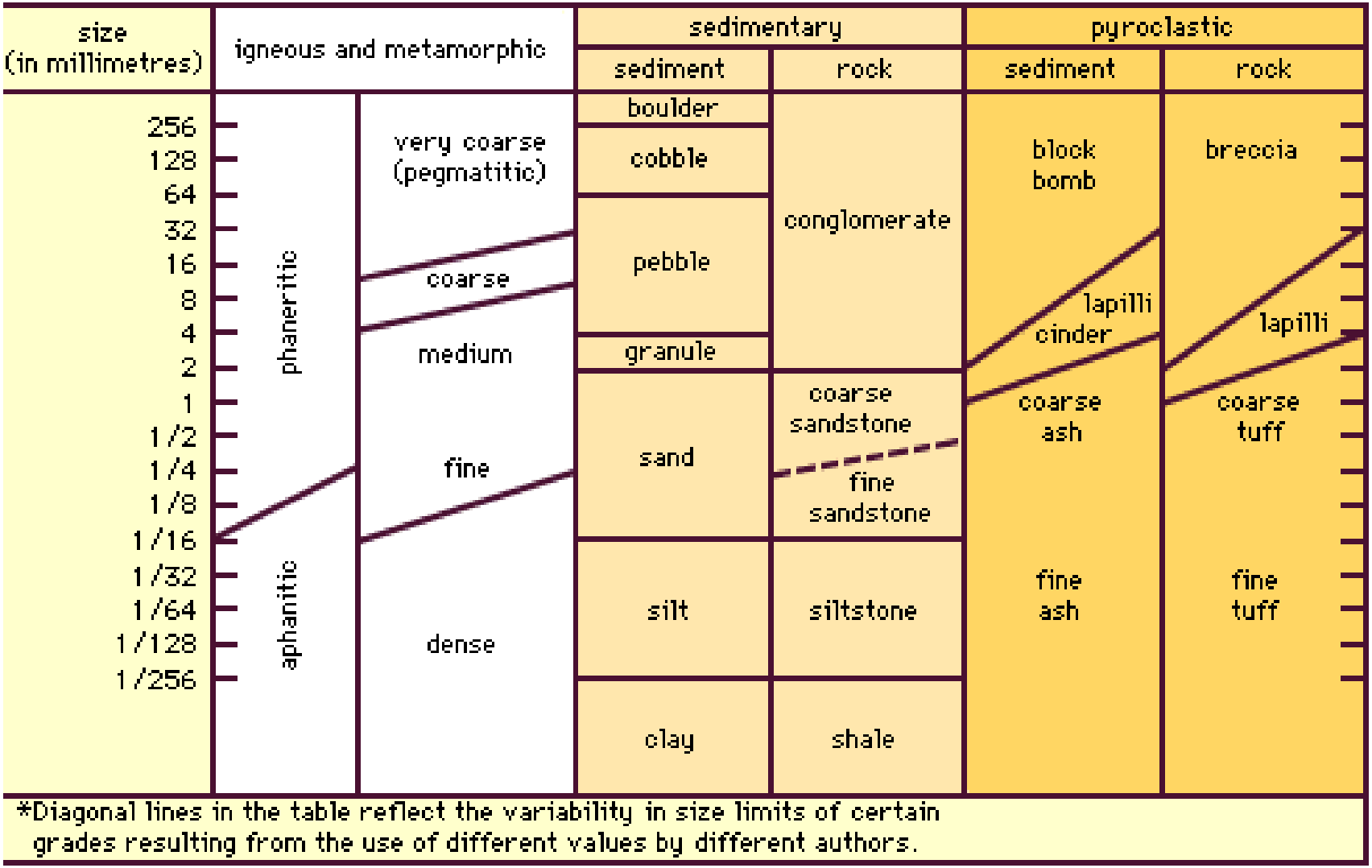
Mode of Origin:

- ✓Precipitated from water (non-clastic, chemical or inorganic limestone),
- ✓ Secreted by marine organisms such as algae and coral (biochemical limestone),
- ✓From the shells of dead sea creatures (bioclastic limestone).
- ✓From the cementation of sand and / or mud by calcite (clastic limestone), and these often have the appearance of sandstone or mudstone.

Uses: In the production of cement, lime fertilizer, paper, petrochemicals, pesticide, glass etc. Also as dimension stone for decoration of walls and floors.




Common textural terms of rocks



*Diagonal lines in the table reflect the variability in size limits of certain grades resulting from the use of different values by different authors.

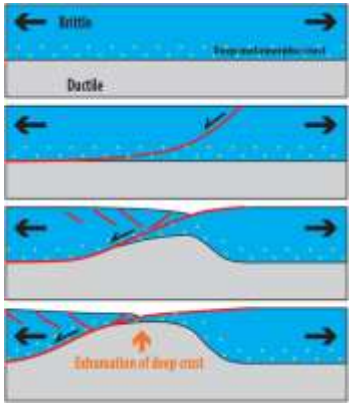
Metamorphic Rocks

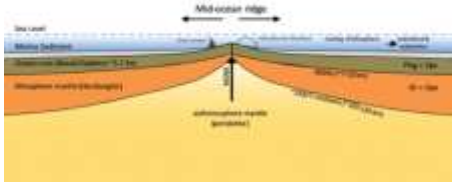
Metamorphism : Metamorphism is the alteration of pre-existing rocks in the solid state due to changes in temperature and pressure.

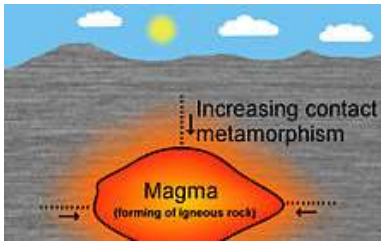
The existed rocks (Igneous,Sedimentay) recrystallize into new rocks without melting, when they subjected to temperatures between 150 to 850 °C and elevated pressure between 100 to 300Mpa and of chemically active fluids.

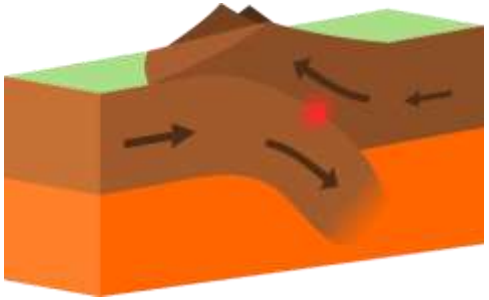
Metamorphic rocks extensively found in

- ✓ Orogenic belts
- ✓ Metamorphic core complexes
- ✓ Granite greenstone belts
- ✓ Mid oceanic ridges
- ✓ Contact aureoloes

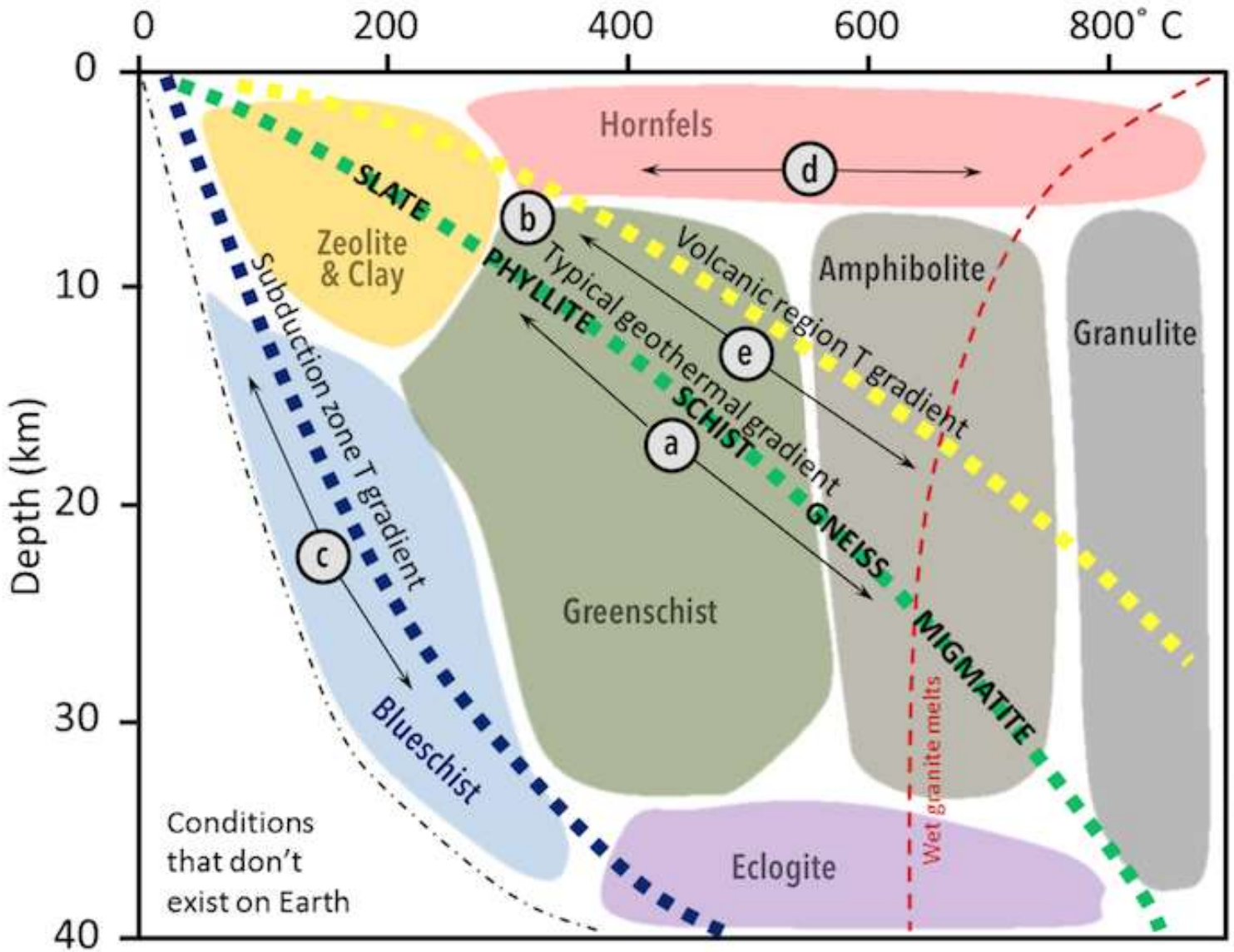


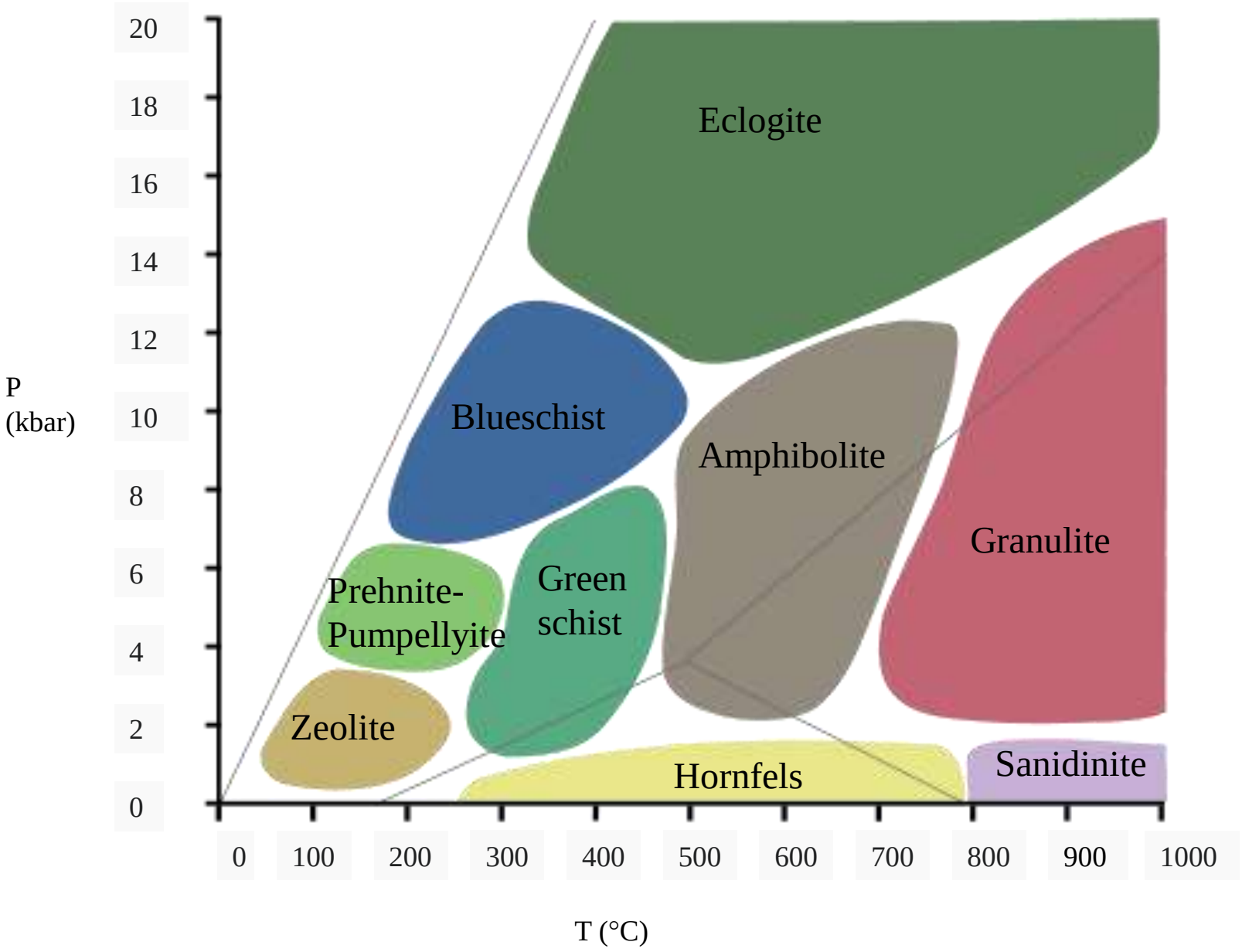






Metamorphic Facies




Eclogite
Blueschist
Amphibolite
Granulite
Prehnite-
Pumpellyite
Green
schist
Zeolite
Hornfels
Sanidinite
P
(kbar)
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
T (°C)

Types of Metamorphism

Regional metamorphism: Regional metamorphism occurs over large areas and generally does not show any relationship to igneous bodies.

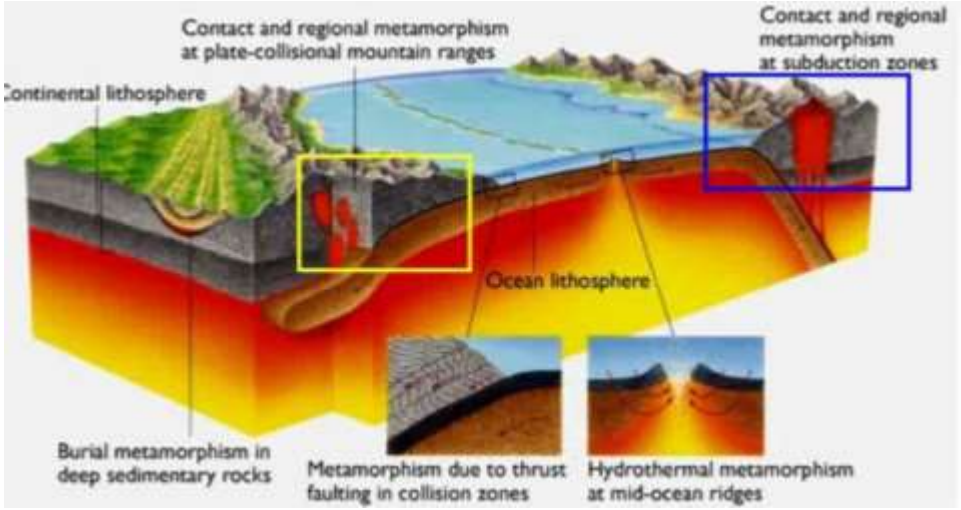
Covers large areas associated with mountain ranges, particularly those associated with convergent tectonic plates or the roots of previously eroded mountains.

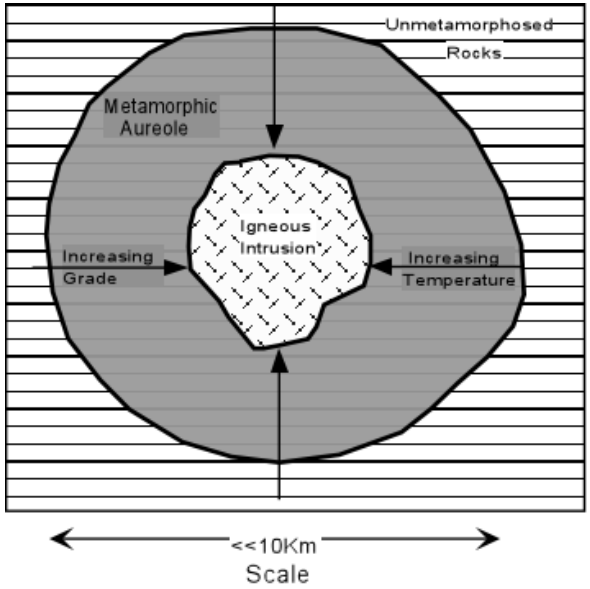
Contact metamorphism: Contact metamorphism occurs adjacent to igneous intrusions and results from high temperatures caused by the intrusion of magma into cooler country rock.

Hydrothermal metamorphism: As the result of the interaction of a rock with a high-temperature fluid of variable composition. The hydrothermal fluid may be magmatic (originate in an intruding magma), circulating groundwater, or ocean water.

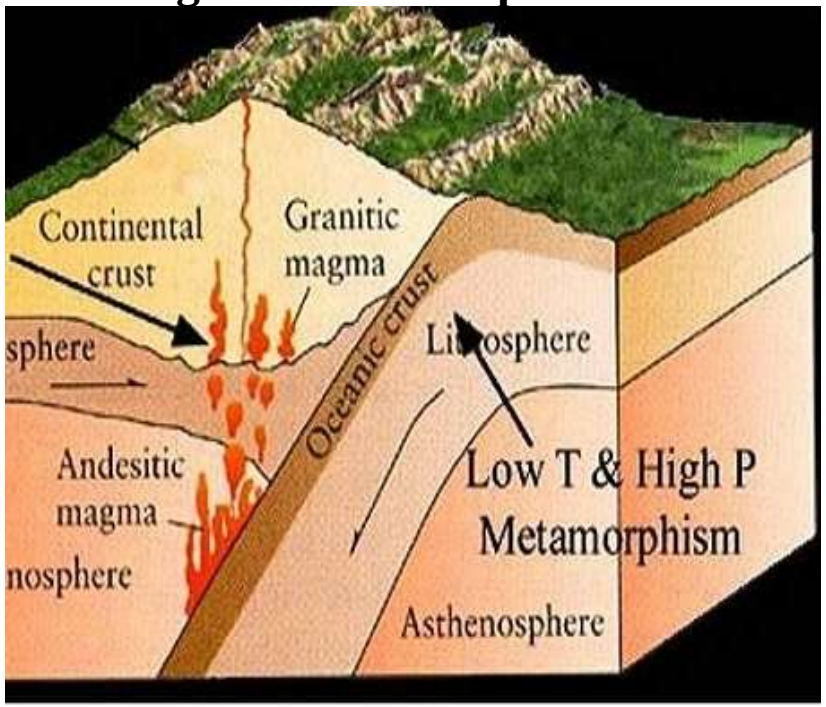
Shock metamorphism: Occurs when an extraterrestrial object (a meteorite for instance) collides with the Earth's surface. Impact metamorphism is, therefore, characterized by ultrahigh pressure conditions and low temperature.

Dynamic metamorphism: is associated with zones of high to moderate strain such as fault zones.

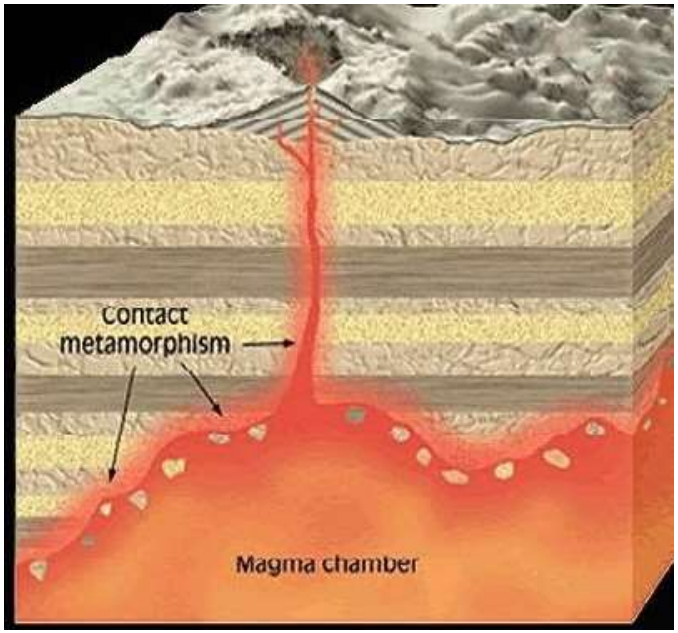




Regional metamorphism



Contact metamorphism



Metamorphic rocks can be classified based on mineral assemblage, texture, protolith, and bulk chemical composition of the rock.

classification based on texture and protolith as.

I.Based on texture

- ✓Foliated (have aligned mineral crystals)
  - Slate
  - Phyllite
  - Schist
  - Gneiss
- ✓N**on-foliated(**do not have aligned mineral crystals**)**.
  - Marble
  - Quartzite
  - Hornfels

II.Based on Protolith

- ✓Granite------Granite gneiss
- ✓Basalt-------Amphibole Gneiss
- ✓Sandstone------Quartzite
- ✓Limestone------Marble
- ✓Mudrock or Shale------Slate-----Phyllite-------Schist--------Gneiss

Protolith	Very Low Grade 150-300°C	Low Grade 300-450°C	Medium Grade 450-550°C	High Grade Above 550°C
Mudrock	slate	phyllite	schist	gneiss
Granite	no change			granite gneiss
Basalt	chlorite schist		amphibolite (amphibole gneiss)	
Sandstone	no change	little change	quartzite	
Limestone	little change	marble		

Note: Temperature ranges are approximate

Metamorphic Rock Structures/Textures

I. Foliated

- **Slaty,Phyllitic and Schistose.**
- **Gneissose**

II.Non Foliated

- **Granulose**
- **Hornfelsic**
- **Cataclastic**

Schistose structure: Due to directed pressure by dynamo-thermal metamorphism, minerals in metamorphic rock (*such as mica, chlorite, talc, and amphiboles*) appears as flaky, lamellar, tabular, rodlike, and highly-cleavable minerals as layers, and folia (more or less parallel bands).

Slaty, Phyllitic and Schistose.

Gneissose or Gneissic structure: A banded structure in which the minerals segregated into discontinuous bands, each of which is dominated by one or two minerals.

Gneissose

Granulose or Granoblastic: structure is due to the predominance of equidimensional minerals, such as quartz, felspar, pyroxene, calcite, etc., in a metamorphic rock.

Granulose

Hornfelsic: Fine-grained, granular interlocking grains, possibly of variable shapes and sizes.

Cataclastic: Resistant minerals in rocks may remain unaffected, while the softer minerals are powdered to fine material.

Cataclastic

Slaty,Phyllitic and Schistose.

Gneissose

Granulose

Cataclastic

Structures/Textures of Metamorphic Rocks

Gneiss

Texture - Foliated, foliation on a scale of cm or more.

Grain size -Medium to coarse grained; can see crystals with the naked eye.

Colour - Variable - generally alternating lighter and darker sub-parallel discontinuous bands.

Mineralogy - Felsic minerals such as feldspar (orthoclase plagioclase) and quartz generally form the light coloured bands; mafic minerals such as biotite, pyroxene (augite) and amphibole (hornblende) generally form the dark colored bands; garnet porphyroblasts common.

Parent Rock(Protolith): Granite,Slate,Phyllite, Shist.

Mode of origin: Metamorphism of Granite.
Uses - dimension stone for building facings, paving etc.

Gneiss

Quartzite

Texture - Granular.

Grain size: Medium grained.

Colour - Variable - pure quartzite is white but quartzite exists in a wide variety of colours.

Mineralogy: Quartz.

Mode of origin: Formed by metamorphism of sandstone.

Parent Rock(Protolith):Sandstone

Uses:source of silica for metallurgical purposes, and for the manufacture of brick. As aggregate in the construction as armour rock for sea walls; dimension stone for building facings, paving etc.

Quartzite

Schist

Texture: Foliated, foliation on mm to cm scale.

Grain size: Fine to medium grained.

Colour: Variable - often alternating lighter and darker bands, often shiny.

Mineralogy:Mica minerals (biotite, chlorite, muscovite),quartz and plagioclase often present as monomineralicbands, garnet porphyroblasts common.

Mode of origin: Formed from shale,slate and phyllite.

Parent Rock(Protolith): Shale,slate,Phyllite.

Uses: Generally used as a decorative rock, e.g. walls, gardens etc; high percentage of mica group minerals precludes its use in the construction.

schist

slate

Texture: Foliated, foliation on a mm scale. **Grain size**: Very fine-grained; crystals not visible to the naked eye.

Colour: Variable - black, shades of blue, green, red, brown and buff.

Mineralogy: Contains mica minerals (biotote, chlorite, muscovite) which typically impart a sheen on foliation surfaces; can contain cubic pyrite porphyroblasts

Mode of Origin: Metamorphism of shale.

Parent Rock(Protolith): Shale,Mud rock.

Uses:Extensively used for roof and floor tiles, and blackboards.

slate

Marble

Texture: Granular.

Grain size: Medium grained.

Colour: Pure marble is white but marble exists in a wide variety of colors.

Mineralogy: Calcite.

Mode of origin: Metamorphism of limestone.

Parent Rock(Protolith): Limestone

Uses:Building stone; dimension stone for building facings, paving etc; cut into blocks and cut for monuments, headstones etc.

Marble

ROCK CYCLE

Crystallization

Igneous Rocks

Magma

Weathering, Erosion and Deposition

Deep Burial Melting

Metamorphic Rocks

Sediments

Heat(200°C to 850°C) **and Pressure (**100 to 300 Mpa)

Compaction, Cementation

Sedimentary Rocks

Questions

1. How igneous rocks are classified according to their occurrences
2. Describe the different types of rocks. Give the classification, texture of sedimentary rocks?
3. What are the factors of metamorphism, describe the structures or textures of metamorphic rocks?
4. What are the physical identification properties of the rocks(i)Quartzite (ii)Marble (iii) Schist (iv)Slate (v) Gneiss.